growth energy™
America's Ethanol Supporters

701 8th Street, NW, Suite 450, Washington, D.C. 20001
PHONE 202.545.4000 FAX 202.545.4001 GrowthEnergy.org

# GROWTH ENERGY COMMENTS ON "BIOFUELS AND THE ENVIRONMENT: THIRD TRIENNIAL REPORT TO CONGRESS (EXTERNAL REVIEW DRAFT)"

Docket ID No. EPA–HQ–ORD–2020–0682

Growth Energy appreciates the opportunity to provide comments for the U.S. Environmental Protection Agency's (EPA's) consideration on the draft *Biofuels and the Environment, Third Triennial Report to Congress* ("Draft Triennial Report").[1] Growth Energy is the world's largest association of biofuel producers, representing 90 biorefineries that produce nearly 9 billion gallons annually of low-carbon renewable fuel and 107 businesses associated with the biofuel production process. Together, our members are working to bring better and more affordable choices at the fuel pump to consumers and protect the environment for future generations. We are committed to helping our country diversify its energy portfolio to support more green energy small businesses and jobs, sustain family farms, and reduce the costs of transportation fuels for consumers.

Biofuels are crucial to decarbonizing the transportation sector. Over 99% of light duty vehicles and even higher percentages of medium- and heavy-duty vehicles, maritime vessels, and aircraft are currently powered by liquid fuels.[2] The collective transportation fleet is expected to continue to be powered by liquid fuels for decades.[3] Therefore, the most immediate pathway to meaningfully reduce greenhouse gas (GHG) emissions in the transportation sector is to decarbonize liquid fuels through the displacement of conventional petroleum fuels with biofuels and biofuel blends.

In light of the significant potential for biofuels to deliver low-cost, low-carbon fuel options that make meaningful progress in reducing GHG emissions, it is critical that EPA relies on the best available and most credible science in conducting its environmental assessments. Growth Energy has consistently provided EPA the latest studies on lifecycle assessment, as well as objective, credible information on environmental impacts, to ensure it relies on sound science in making biofuels and climate change regulation and policy.

Attached to these comments, we are submitting an analysis of the Draft Triennial Report, prepared by environmental and economic experts at Ramboll and Net Gain Ecological Services (NGES), which includes a technical evaluation of EPA's attribution methodology and discussion

[1] Congress mandated that EPA publish Triennial Reports to advance the scientific understanding of past and potential impacts of the Renewable Fuel Standard (RFS) on the environment. *See* Energy Independence and Security Act of 2007 (EISA), Public Law 110-140 § 204 (Dec. 19, 2007).
[2] U.S. DOE, DOT, EPA & HUD, *The U.S. National Blueprint for Transportation Decarbonization: A Joint Strategy to Transform Transportation* (Jan. 2023) at 57–58, https://www.energy.gov/sites/default/files/2023-01/the-us-national-blueprint-for-transportation-decarbonization.pdf.
[3] *Id.*

of potential ecological and biodiversity impacts ("Ramboll Supplemental Report," attached here as Exhibit 1). This analysis supplements a previous comprehensive report from Ramboll and NGES submitted by Growth Energy in response to EPA's proposed rulemaking "setting" renewable fuel volumes for 2023 to 2025 (Renewable Fuel Standard (RFS) Set rulemaking), which debunks much of the flawed science concerning biofuels' effect on land use change (LUC) and other environmental impacts ("Ramboll Report," attached here as Exhibit 2). That previous study by Ramboll and NGES, together with their new supplemental analysis, add to the wealth of public and private data concluding that there is "no demonstrated causal link between the [RFS], and [LUC]" or other impacts requiring further ESA reviews.[4] Among other key findings, Ramboll and NGES conclude that "[m]odeling indicates that the statistical dependency between the implied conventional volume and corn prices is non-existent to very weak,"[5] and the proposed renewable volume obligations (RVOs) for 2023-2025 are "are likely to have minimal or no effects on water quantity, quality or LUC."[6]

Growth Energy is also submitting a new analysis by AIR, Inc. which identifies important scientific literature on air quality that was overlooked by the Draft Triennial Report ("AIR, Inc. Report" attached here as Exhibit 3). Additionally, we are resubmitting a report, initially submitted in response to the RFS Set rulemaking, conducted by Environmental Health & Engineering, Inc. (EH&E), which highlights the important additional environmental and public health benefits of higher ethanol blends and adds to the literature exposing flawed science on LUC ("EH&E Report," attached here as Exhibit 4). Among the report's conclusions were:

- Better science, based on newer and more accurate modeling techniques, shows that the carbon intensity of corn ethanol is two to four times lower in terms of indirect land use change (iLUC) than previously thought.
- The carbon intensity estimates for the iLUC associated with corn ethanol have been converging on lower values when considering the best available science and improved models.
- Corn ethanol reduces GHG emissions by 46% compared to regular gasoline.
- As the percentage of ethanol blended with gasoline increases, the content of aromatics (hazardous air pollutants) in the fuel decreases.
- Higher ethanol fuel blends offer a valuable opportunity to reduce particulate matter concentrations and risk of adverse cardiovascular and respiratory outcomes.[7]

In issuing its Third Triennial Report, it is critical that EPA take these latest studies into account and provide a balanced view of the environmental impacts associated with biofuels, reflecting the best available science. It is also time that EPA cease relying on and repeatedly citing to flawed data on land use conversion, which has been thoroughly debunked and dismissed by the nation's top climate scientists, including those at the U.S. Department of Agriculture (USDA), the U.S. Department of Energy, Argonne National Laboratory, and University of Illinois-Chicago, among others. Moreover, in the interest of providing the public with a full and accurate picture, it is also important that EPA acknowledge the well-documented adverse

[4] Exhibit 2, Ramboll Report at 1.
[5] *Id.* at 7.
[6] *Id.* at 1.
[7] *See* Exhibit 4, EH&E Report.

environmental impacts associated with the petroleum-based fuels that biofuels displace in the transportation fuels market.

As an initial matter, EPA's Draft Triennial Report correctly makes several important findings, including that:

- Non-RFS factors that are known to influence the market explain much of the increase in ethanol production and consumption in the United States.[8]
- Some data indicate that the RFS program has **no effect whatsoever** on domestic corn ethanol production or LUC.[9]
- The extent of current cultivated crop acreage is below historic levels of crop cultivation.[10]
- The USDA Long Term Agricultural Projections suggest that corn acreage and corn used for ethanol will remain relatively stable from 2020 to 2025, declining slightly thereafter.[11]
- Existing scientific literature on ecosystems impacts is not specific to the effects of corn and soybean grown for biofuels.[12]
- The biofuel industry is consistently reducing emissions as it matures.[13]

Nevertheless, the Draft Triennial Report suffers from several pervasive flaws that must be corrected. These flaws distort EPA's estimates and substantially overstate the nature and scale of environmental impacts attributable to the RFS. EPA must correct these flaws and avoid reliance on repeatedly debunked studies in the final Triennial Report. These flaws are described in detail in the Supplemental Ramboll Report and AIR, Inc. report that demonstrate, among other things, that:

- EPA's methodology for identifying LUC attributable to the RFS is fundamentally flawed because it includes a high-end estimate of 20% that is not supported by any single study in the scientific literature. This flaw permeates many sections of the Draft Triennial Report that incorporate the 20% estimate, including EPA's discussion of ecosystem and biodiversity impacts.[14]
- EPA's discussion of potential ecosystem and biodiversity impacts fails to adequately acknowledge that it does not connect any species impacts to the RFS program. Instead, these chapters arbitrarily present a list of species whose habitats may be in geographic proximity to areas where evidence of agricultural conversion is possible (but not proven), with no consideration of whether the land conversion (if any) was *caused by* the RFS, and no consideration of species-specific factors such as life history, population trends, and

[8] Draft Triennial Report at ES-2.
[9] *Id.* at IS-3 (potential range of cropland increases attributable to the RFS program includes 0%).
[10] *Id.* at 5-2.
[11] *Id.*
[12] *Id.* at 12-6.
[13] *Id.* at 8-3.
[14] Exhibit 1, Supplemental Ramboll Report at Section 2.

non-agricultural stressors. Closer analysis of several species of concern identified by EPA reveals that population changes are likely wholly unrelated to the RFS program.[15]

- EPA's air quality analysis fails to consider several studies showing emissions decreases associated with use of ethanol-blended fuels, and relies on studies which overstate and/or misattribute negative air quality impacts from ethanol.[16]

The expert reports attached to this letter also provide specific recommendations for EPA to address these errors in the final Triennial Report. We appreciate EPA's consideration of these important issues.

## I. EPA's Attribution Analysis Is Fundamentally Flawed

Previous Triennial Reports have been unable to attribute any environmental impacts specifically to the RFS program. As we have detailed at length in several recent comments to EPA, the likelihood of a demonstrable causal chain between RFS volumes and LUC is extremely remote, and most likely non-existent due to the highly attenuated nature of the relationship and a myriad of intervening factors.[17] Despite this, the Draft Triennial Report attempts for the first time to assign a range of estimates that attribute environmental impacts to the RFS program. This proposed range estimates that 0-20% of LUC from all sources is attributable to the RFS program. However, as detailed in the Supplemental Ramboll Report, EPA's methodology for determining the maximum value in this range suffers from a number of fundamental errors.

Most importantly, EPA's high-end estimate that up to 20% of all LUC may be attributable to the RFS program is not supported by any study that EPA cites. Instead, as the Supplemental Ramboll Report explains, EPA cobbles together a value by extracting the highest individual inputs across studies which differ substantially in methodology, scope, and purpose.

For example, Taheripour et al. (2022) finds that from 2004 to 2016, the highest annual amount of incremental increase in domestic ethanol production attributable to the RFS program was 2.1 billion gallons in 2016. Applying this value to a specific series of factors in a model, Taheripour et al. concludes that the RFS program resulted in 160,000 acres of cropland expansion between 2011 and 2016.

In contrast, EPA takes the 2.1 billion gallon figure from Taheripour et al. completely out of context and multiplies it by a cropland expansion coefficient of 884,000 acres per billion gallons—a figure found in a completely different study, Li et al. (2019), conducted for a different purpose. Critically, this Li et al. study was only intended to evaluate cropland expansion *within a 25-mile radius of bioethanol facilities*—where expansion might be expected to be the highest. Further, the coefficient measured by Li et al. represents the relationship between plant *capacity* and *local* LUC, but EPA inappropriately extrapolates this coefficient to estimate the relationship between ethanol *production* and *national* LUC. As a result, as the Supplemental Ramboll Report

---

[15] *Id.* at Sections 3-5.
[16] Exhibit 3, AIR, Inc. Report.
[17] *See* Growth Energy Comments on EPA's Renewable Fuel Standard (RFS) Program: Standards for 2023–2025 and Other Changes, EPA-HQ-OAR-2021-0427-0796, (Feb 10, 2023) ["2023 Growth Energy Comments"]; Growth Energy Comments on EPA's Proposed Renewable Fuel Standard Program: RFS Annual Rules, EPA-HQ-OAR-2021-0324-0521, (Feb. 4, 2022).

demonstrates, EPA creates a final value that is not supported by a single study that the agency cites—and is over **12.5 times larger** than the Taheripour et al. study on which it partially relies. The Supplemental Ramboll Report describes a series of similar issues with the mismatched combination of values EPA uses to calculate the high-end value in its estimated range of attribution.

EPA's disjointed approach results in an excessively wide and misleading range of attribution figures. Most concerningly, EPA then relies upon this faulty attribution range as the basis to evaluate the various environmental impacts considered in the Draft Triennial Report. As the Supplemental Ramboll Report explains, EPA must reconsider its approach to producing a high-end attribution estimate, and then adjust its environmental impacts analyses using the new range. Ramboll and NGES present "a strong case" that there is "either no effect or near zero cropland expansion" attributable to the RFS program across all years.[18]

## II. EPA's Species Analysis Does Not Connect Any Species Impacts to the RFS Program

Chapters 12, 13, and 14 of the Draft Triennial Report address potential impacts to terrestrial, aquatic, and wetland ecosystem health and biodiversity, respectively. As the Ramboll Supplemental Report explains, each of these chapters discusses potential species impacts in general without any evaluation of the specific impacts of the RFS program. This is in tension with the statute, which explicitly directs EPA in the Triennial Reports to present an evaluation of past and future environmental impacts *of the RFS program*.[19] As EPA notes, impacts of biofuels generally, or of the agricultural sector as a whole, are "not the intended focus of this report series."[20] As the Ramboll Supplemental Report suggests, EPA should "remove extraneous and potentially misleading discussion of environmental effects which have not been shown to be causally linked to the RFS program,"[21] and which extend beyond the scope of the Triennial Reports set by Congress. At a minimum, EPA must clarify that the potential species impacts discussed in Chapters 12, 13, and 14, which EPA does not connect to the RFS program, are entirely speculative and theoretical.[22]

For terrestrial species, EPA correctly acknowledges that any impacts to terrestrial biodiversity and species would be dependent on whether and where RFS-induced LUC is occurring. However, as Ramboll and NGES have repeatedly demonstrated, any causal link between the RFS and LUC is either weak or non-existent.[23] Despite this, EPA relies on a set of arbitrary proximity criteria to identify 27 threatened and endangered species with critical habitat within a 1-mile radius of areas where it is possible that 10 acres or more of land conversion to corn or soy production has occurred.[24] Yet EPA never explains how land conversion that occurs a mile away from critical habitat is relevant to species health. Critical habitat designations

---

[18] Exhibit 1, Supplemental Ramboll Report at 6.
[19] EISA, Public Law 110-140 § 204 (Dec. 19, 2007) ("the Administrator of the Environmental Protection Agency, in consultation with the Secretary of Agriculture and the Secretary of Energy, shall assess and report to Congress on the impacts to date and likely future impacts of the requirements *of section 211(o) of the Clean Air Act*…") (emphasis added).
[20] Draft Triennial Report at 2-2.
[21] Exhibit 1, Supplemental Ramboll Report at 3.
[22] *Id.*
[23] Exhibit 2, Ramboll Report at 4.
[24] Draft Triennial Report at 12-16.

delineate the land area that is "essential to the conservation" of the species, including the necessary "space for individual and population growth and for normal behavior."[25] When EPA's proximity analysis is properly reduced to species with cropland expansion that might have occurred within the zone of designated critical habitat, the list of species is reduced to only six species.

Critically, however, this list of six species in proximity to cropland expansion is only relevant if some material proportion of that expansion is actually attributable to the RFS program. As discussed above and in the Supplemental Ramboll Report, the amount of cropland expansion attributable to the RFS program is very likely to be "close to zero or potentially zero," and EPA's method for calculating the high-end estimate of its attribution range is fundamentally flawed.[26]

Equally arbitrary is EPA's fixation on proximity to LUC as the **only criteria** to identify potentially impacted species. EPA's analysis fails to evaluate whether agricultural land use conversion is a key stressor for the particular species that EPA lists. No consideration is given, for example, to species-specific factors such as life history, habitat preferences, seasonality, population trends, or historic and current stressors. Closer scrutiny of the many factors impacting species populations dispels any suggestion that the RFS is a contributing factor to species harms. For example, the Supplemental Ramboll Report explains that:

- Whooping Crane populations have "steadily grown with no dip apparent after the implementation of the RFS" in 2007.[27] In particular, the Aransas Wood Buffalo population, which migrates through major ethanol producing regions in the Midwest, has seen "considerable growth."[28] And neither the U.S. Fish and Wildlife Service (USFWS) nor the International Union for Conservation of Nature list agriculture among the key stressors for the species.

- Poweshiek Skipperling populations were in steep decline long before the RFS program was implemented and have not been seen in many Midwestern states since before the RFS program began. Given this timeline, the species has been absent from most corn producing regions "10 years or more before the RFS could have had any impact."[29]

- Indiana Bat populations have suffered significant recent declines as a result of white nose syndrome (WNS), a particularly devastating fungal disease which has caused a 90% decline in populations within the affected area. Throughout the entire existence of the RFS program, "the most significant threat to the Indiana bat and other bat species has been WNS."[30]

---

[25] U.S. Fish and Wildlife Service, *Critical Habitat: What is it?* (Mar. 2017) at 1, https://www.fws.gov/sites/default/files/documents/critical-habitat-fact-sheet.pdf.
[26] Exhibit 1, Supplemental Ramboll Report at 1.
[27] *Id.* at 8-9.
[28] *Id.* at 8.
[29] *Id.* at 9.
[30] *Id.* at 10.

EPA's discussion of aquatic species includes many of the same faults. Again, EPA presents a solely proximity-based analysis of species with no explanation or evaluation of a connection to the RFS program and no consideration of species-specific factors. EPA's reliance on proximity to land conversion as the sole criteria to identify species impacts makes even less sense in the context of aquatic species, which do not have terrestrial habitats. For example, EPA does not consider the existence or scope of any hydrologic connections between the aquatic species' critical habitat and the cropland conversion areas that could potentially lead to impacts on the species. It is not surprising then that a closer analysis of aquatic species included in the Draft Triennial Report's list demonstrates that the RFS is unlikely to have any significant impact on the species' population health. For example, the Supplemental Ramboll Report finds that:

- Topeka Shiner populations are increasing, and according to the Center for Biological Diversity are primarily threatened by dams, gravel-removal operations, water pollution from livestock, and urbanization—none of which have any relation to the RFS program.[31]

- Arkansas River Shiner populations are primarily affected by stressors related to the construction of dams, according to the USFWS.[32]

- Gulf Sturgeon critical habitat, which exists east of the Mississippi River, has little to no overlap with Gulf of Mexico (GoM) dead zones, which occur west of the Mississippi River. Indeed, "the lack of temporal and geographic association between the GoM hypoxic zone and critical habitat and use of that habitat by Gulf sturgeon suggests no potential impact to this endangered species from the GoM dead zone."[33] Further, there is also no evidence attributing hypoxia from nutrient loading in the GoM to the RFS program. Since the RFS program was implemented in 2007, the nutrient load to the GoM has actually *decreased*.[34]

- Pink Mucket populations are primarily affected by navigation activities, releases from reservoirs, mining activities, inadequate treatment of wastewater discharges, and factors related to disjunct populations. The USFW 5-Year Report on the species makes no mention of agriculture, let alone the RFS program.[35]

Similarly, for wetland species, EPA relies on a proximity analysis with no consideration of species-specific factors. For example, piping plover populations are primarily threatened by habitat loss due to commercial, residential, and recreational developments; effects of water control structures on nesting habitat; vehicle and pedestrian use of beaches; harassment or mortality of birds by pets; and predation. As the Supplemental Ramboll Report notes, "[w]hile land use change from urban development was listed as a potential threat, LUC from agriculture is not recognized as a significant threat to these populations."[36]

---

[31] *Id.* at 12.
[32] *Id.*
[33] *Id.* at 14.
[34] *Id.* at 13.
[35] *Id.* at 15.
[36] *Id.* at 16.

## III. EPA Fails to Consider Relevant Studies Demonstrating the Many Air Quality Benefits of Ethanol

As discussed in detail in attached comments by AIR, Inc., the Draft Triennial Report fails to incorporate recent literature demonstrating that higher ethanol-blended fuels have many air quality benefits as compared to E0 and lower level ethanol-blends.[37] These include reductions in emissions of hydrocarbons, carbon monoxide (CO), nitrogen oxide (NOx), and particulate matter (PM). In particular, EPA should incorporate the California Air Resources Board 2022 E15 Study[38] in its final Triennial Report. The key findings of this report include:

- Cold-start and weighted total hydrocarbon emissions showed statistically significant reductions of 6% and 5%, respectively, for E15 compared to E10.
- For the cold-start nonmethane hydrocarbon emissions, E15 showed a 7% statistically significant reduction compared to E10.
- NOx emission differences were not statistically significant between the two fuels.
- For the cold-start and hot-running phases, PM mass emissions showed statistically significant reductions of 17% and 54%, respectively, for E15 compared to E10.
- Particle number emissions for E15 were 12% lower than E10, at a statistically significant level.
- For ethylbenzene emissions, E15 showed a statistically significant reduction of 11% compared to E10.
- Non-methane organic gas (NMOG) emissions trended lower for E15 compared to E10. Like NMOG, ozone forming potential showed a decreasing trend for E15 compared to E10, indicating that the introduction of E15 in the California gasoline market will likely not contribute to increases in ozone formation.[39]

EPA also fails to acknowledge significant limitations in the reports it relies upon in the Draft Triennial Report, including the Anti-Backsliding Study, which Growth Energy and AIR, Inc. previously provided comments on.[40] Most significantly, due to various methodological issues with the fuel properties used in EPA's modeling, the Anti-Backsliding Study erroneously overestimates even slight increases in certain pollutants (NOx, volatile organic compounds (VOCs), and PM). At the same time, the study underestimates the benefits of ethanol-blended

---

[37] *See* Exhibit 3, AIR, Inc. Report.
[38] Karavalakis, Durbin, & Tang, *Final Report, Comparison of Exhaust Emissions Between E10 CaRFG and Splash Blended E15,* Prepared for: California Air Resources Board (CARB), Growth Energy Inc./Renewable Fuels Association (RFA), and USCAR (Jan. 2022).
[39] *Id.*
[40] *See* Attachment A to Exhibit 3, Growth Energy Comments on the Proposed Anti-Backsliding Determination for Renewable Fuels and Air Quality, EPA-HQ-OAR-2020-0240-0012 (July 13, 2020).

fuel in reducing emissions of potent air toxics such as benzene and 1,3 butadiene, as well as PM and CO.[41]

In addition, we are resubmitting a recent report from EH&E that EPA should consider in finalizing the Triennial Report.[42] As noted in our submission to EPA regarding the proposed 2023-2025 RFS rule:[43]

> Ethanol boosts octane in fuel without the harmful impacts of alternative octane-boosting fuel additives, including methyl tert-butyl ether (MTBE), lead, and aromatics (including benzene, toluene, ethylbenzene, and xylene). Indeed, the level of aromatics in fuel decreases by about 7% for every 10% by volume increase in ethanol content.[44] Decreasing aromatics in fuel has direct impacts on tailpipe emissions, with higher-ethanol fuels resulting in lower emissions of particulate matter (PM), black carbon (BC), particle number (PN), benzene, toluene, ethylbenzene, m/p-xylene and o-xylene (BTEX), and 1-3 butadiene as compared to higher-aromatic fuels.[45]
>
> For PM emissions in particular, recent studies have demonstrated substantial benefits from higher blends of ethanol in fuel. For example, a 2022 study by EH&E observed 15-18% decreases in PM emissions for each 10% increase in ethanol content.[46] California Air Resources Board (CARB) found even greater benefits, concluding that the 5% increase in ethanol content between E10 and E15 fuels reduced PM emissions by 18% and cold-start emissions by 17%.[47]

EH&E's report concludes that there is "considerable support" from the scientific literature that substitution of ethanol for aromatics results in net public health benefits.[48] EPA's failure to consider this literature in the Draft Triennial Report results in a distorted view of ethanol's air quality impacts. EPA's final Triennial Report should discuss and incorporate in its findings these additional analyses.

Further, EPA correctly notes important trends regarding emissions from ethanol production which should be better emphasized throughout the Triennial Report. First, ethanol plants are generally located in non-urban areas which have better overall air quality than urban areas, where many petroleum refineries are located. Urban areas have higher concentrations of VOCs, sulfur oxides, $PM_{2.5}$, $PM_{10}$, and NOx, which "is important as the detrimental effects of these pollutants are associated with human exposure to the associated particulates and ozone."[49]

---

[41] *Id.*
[42] *See* Exhibit 4, EH&E Report.
[43] 2023 Growth Energy Comments at 37.
[44] Kazemiparkouhi et al. 2022a.
[45] Badrawada and Susastriawan 2019; Clark et al. 2021; Gunst 2013; Karavalakis 2018; Karavalakis et al. 2012, 2022; Kazemiparkouhi et al. 2022c; Mourad and Mahmoud 2019; ORNL et al. 2016; NREL 2013; Roso et al. 2019; Theiss 2016; Wayson 2016.
[46] Kazemiparkouhi et al. 2022c.
[47] Karavalakis et al. 2022.
[48] Exhibit 4, EH&E Report at 55.
[49] Draft Triennial Report at 8-42.

Additionally, as the biofuels industry has matured, it has consistently reduced its process emissions.[50]

## IV. EPA Must Correct the Flaws in the Draft Triennial Report

To correct the various shortcomings in the Draft Triennial Report discussed above, we urge EPA to take the following actions in its final report, along with the other recommendations discussed above:

- Correct the unsupported high-end estimate in EPA's LUC attribution analysis and re-consider all discussion of potential environmental impacts that rely on this estimate.

- Remove extraneous and potentially misleading discussion of environmental impacts that have not been shown to be causally linked to the RFS program. At a minimum, clarify that the potential ecosystem and biodiversity impacts discussed in Chapters 12, 13, and 14 are speculative and theoretical because the Draft Triennial Report merely identifies species habitat in proximity to LUC without identifying any species-specific impacts caused by the RFS.

- Include information on population trends and species-specific stressors to provide additional context beyond critical habitat proximity to LUC.

- Incorporate additional studies into the final Triennial Report's analysis of air quality impacts.

These corrections are necessary to satisfy EPA's obligations to incorporate the best available science into actions implementing the Clean Air Act. Biofuels are an essential tool for combatting climate change with enormous potential for decarbonizing the transportation fuel sector while bolstering domestic energy security, providing jobs in rural areas, and lowering the price at the pump for consumers. For the full potential of biofuels to be realized, EPA must provide a balanced, credible review of the science on environmental impacts that omits reliance on flawed data and studies that have been discredited by other government agencies and academics.

We appreciate EPA's consideration of these important critiques as it finalizes the Draft Triennial Report.

[50] *Id.*at 8-3.

Sincerely,

Christopher P. Bliley

Senior Vice President of Regulatory Affairs

Growth Energy

# Exhibit List

## Growth Energy Comments on "Biofuels and the Environment: Third Triennial Report to Congress (External Review Draft)"

Docket ID No. EPA–HQ–ORD–2020–0682

| Exhibit Number | Title of Exhibit |
|---|---|
| **1** | Ramboll & Net Gain Ecological Services, *Review of Biofuels and the Environment Third Triennial Report to Congress External Review Draft (ERD)* (March 6, 2023) |
| **2** | Ramboll & Net Gain Ecological Services, *Review of Environmental Effects and Economic Analysis of Corn Prices: EPA's Proposed RFS Standards for 2023-2025* (February 10, 2023) |
| **3** | Air Improvement Resources, Inc., *Comments on Chapter 8 of the "Biofuels and the Environment: Third Triennial Report to Congress (External Review Draft)"* (March 6, 2023) |
| **4** | Environmental Health & Engineering, *Response to Proposed Renewable Fuel Standard (RFS) Program Standards for 2023-2025* (February 10, 2023) |

**Growth Energy Comments on "Biofuels and the Environment: Third Triennial Report to Congress (External Review Draft)"**

Docket ID No. EPA–HQ–ORD–2020–0682

# Exhibit 1

RAMBOLL

ENVIRONMENT
& HEALTH

# Technical Note

## Review of *Biofuels and the Environment Third Triennial Report to Congress External Review Draft (ERD)*

Prepared for **Growth Energy**
Date **March 6, 2023**

## 1 Executive Summary

This technical note summarizes a review performed by Ramboll and Net Gain Ecological Services (Net Gain) regarding the Environmental Protection Agency's (EPA's) draft *Biofuels and the Environment, Third Triennial Report to Congress* (EPA/600/R-22/273), hereafter, RtC3.

In its prior triennial reports, (i.e., EPA 2011; 2018), EPA noted that it was not able to separate the effects of the Renewable Fuels Standard (RFS) Program from general market impacts and other policy effects. In RtC3, EPA makes a new effort to determine the extent to which it can attribute ethanol production/consumption and land use change (LUC) to the RFS Program. EPA finds that from 2002 to 2012, the RFS Program likely played a relatively minor role in increasing corn ethanol production and consumption, contributing between zero to 0.4 billion gallons per year. Since 2013, however, EPA finds that the RFS Program may have played a more important role in the increase of corn ethanol production and consumption, estimating from between zero to 2.1 billion gallons per year.

Based on EPA's estimated range of corn ethanol production and consumption attributable to the RFS Program, RtC3 provides an estimated range of additional cropland acres attributable to the same. Specifically, EPA estimates that the range of additional cropland expansion for the years 2008 through 2016 attributable to the RFS Program is between zero and 2 million acres, or alternatively between zero to 20 percent (%) of total cropland expansion from all causes. We find that both estimates are invalid and overestimate the effects of the RFS.

Ramboll and Net Gain recently prepared a report titled *Review of Environmental Effects of and Economic Analysis of Corn Prices: EPA's Proposed RFS Standards for 2023-2025* (hereafter, Ramboll and Net Gain 2023). The results and conclusions presented in Ramboll and Net Gain 2023 make a strong case for the estimated annual effect of cropland expansion attributable to RFS Program for the years 2008 through 2016 ***to be close to zero or potentially zero****, i.e., the lower end of EPA's range of LUC attributable to the RFS Program.*

Regarding EPA's estimate of the high-end 20% increased cropland expansion due to the RFS Program, we find that EPA's approach is problematic because it synthesizes the highest of high-end factors it could find from all literature, even though each individual factor was developed by various studies using different approaches for different purposes. Notably, EPA uses the highest ethanol production data attributable to the RFS Program of 2.1 billion gallons, which was reported by Taheripour et al. (2022) for the year 2016, to estimate total cropland expansion to the RFS Program of 2 million acres over the years 2008 to 2016. However, EPA disregards the fact that Taheripour et al. (2022) reports ***only 0.16 million acres*** of cropland expansion that could be attributable to the RFS Program for the entire period 2011 to 2016. Therefore, EPA's cropland expansion estimate is 12.5 times that reported by Taheripour et al. (2022). For this reason, and reasons related to other factors used in EPA's approach described herein, we conclude that EPA's high-end estimate of 20% is invalid and caused EPA to significantly overstate the potential environmental impacts of the RFS Program. As explained further below, our literature review and analysis demonstrate that the annual effect of cropland expansion attributable to RFS Program is more likely close to zero or potentially zero. It should also be noted that EPA relied on publications that ignore increases in crop yield and other factors such as the use of dried distiller grain with solubles (a byproduct of ethanol production used for animal feed) and increased efficiencies in ethanol production, which have the effect of offsetting increased cropland expansion. These omissions further diminish the validity of EPA's conclusions.

Regarding terrestrial ecosystem health and biodiversity, EPA claims that the impacts to date from biofuels are "…primarily due to corn and soybean feedstock production…" (page 12-2, lines 22-24) without sufficient scientific support. Notably, this claim rests largely on disputed analyses that unsuccessfully attempt to link impacts to terrestrial biodiversity with the RFS Program.

EPA correctly points out that impacts to terrestrial biodiversity and threatened and endangered (T&E) species hinge on whether [and where] RFS-induced LUC is occurring. However, as previously demonstrated by Ramboll and Net Gain (2023) and detailed in this technical note, there is no quantitative causal link between the RFS and LUC.

Lastly, in EPA's 'new analysis' of potential impacts to T&E species in the RtC3, consideration was not given to species-specific life history, habitat preferences, seasonality, population trends, possible recovery, or historic versus current threats. Rather, EPA's analysis rests on the identification of species potentially at risk based solely on whether 10 acres or more cropland conversion had occurred within one mile of designated critical habitat. EPA presents no technical assessment of the actual risk to these species. As a general recommendation, we urge EPA to revisit its conclusions in this section and remove discussion of impacts which are not shown to be causally connected to the RFS Program. At a minimum, EPA should qualify this discussion as theoretical and acknowledge that a causal association between any effects described and the RFS has not been established.

Regarding aquatic ecosystem health and biodiversity, EPA states that corn and soybean are drivers for adverse effects to aquatic ecosystems and biodiversity and presents a discussion of potential impacts from agriculture in general. To illustrate potential water quality impacts, EPA relies on a water quality modelling exercise for the Missouri River basin that is based on flawed LUC scenarios from Lark et al. (2020). Despite representing an overestimate of potential effects from corn and soy, EPA concludes that biofuels feedstock production in the Missouri River Basin does not affect streamflow and sediment input and has an inconsequential effect on exceedance of water quality criteria for total nitrogen (TN) and total phosphorus (TP). However, in the RtC3's discussion of nutrient inputs, EPA fails to acknowledge that no quantitative causal link has been established between the RFS Program and the potential impacts modeled.

In its analysis of potential impacts to T&E species, EPA applies the same arbitrary proximity criteria they did for terrestrial ecosystems. EPA then discusses potential pathways for impacts to the species identified without any meaningful assessment of risk, and no assessment of a causal association between such risk and the RFS Program. For some of the species EPA identifies, the United States (US) Fish and Wildlife Service and the National Marine Fisheries Service document a range of threats that do not include agriculture. EPA again discusses the Gulf of Mexico (GoM) "dead zone" without acknowledging the overall decrease in TN loading over the period of rapid growth in ethanol production. In addition, EPA identifies gulf sturgeon as a species potentially at risk; however, it fails to acknowledge that the GoM dead zone does not overlap with critical habitat for this species. As a general recommendation, we urge EPA to remove extraneous and potentially misleading discussion of environmental effects which have not been shown to be causally linked to the RFS Program. At a minimum, EPA should qualify this section as speculative and theoretical, and to acknowledge that a causal association between any effects described and the RFS has not been established.

Our review below focused on two primary areas of analysis:

- EPA's estimated range of 0% to 20% of cropland expansion attributed to RFS Program for the years 2008 through 2016.
- Possible effects of cropland expansion on aquatic and terrestrial ecosystem health and biodiversity.

## 2 Cropland Expansion Attributed to the RFS Program

We focus on the estimated cropland expansion attribution because the majority of potential aquatic and terrestrial ecosystem impacts resulting from the RFS would stem from cropland expansion related to biofuels feedstock production. Ramboll and Net Gain recently prepared a report titled *Review of Environmental Effects of and Economic Analysis of Corn Prices: EPA's Proposed RFS Standards for 2023-2025* (hereafter, Ramboll and Net Gain 2023). One of the major areas of focus of this work was an analysis of the impact of the RFS Program on corn prices and corn acres planted. This analysis included three steps:

1. Review of the Proposed Rule and the associated Draft Regulatory Impact Analysis.
2. Review of relevant literature regarding the RFS Program.
3. Development of a series of analytical models to determine whether the RFS is a driving factor influencing corn prices and acres of corn production.

Our literature review as presented in Ramboll and Net Gain 2023 focused on three primary papers:

- Lark et al. (2022): Environmental outcomes of the US Renewable Fuel Standard.
- Austin et al. (2022): A review of domestic land use change attributable to U.S. biofuel policy.
- Taheripour et al. (2022): Economic impacts of the U.S. Renewable Fuel Standard: An *ex-post* evaluation.

As a result of our literature review and analytical modeling we reached the following conclusions:

- Lark et al. (2022) overestimates the impact of RFS Program on corn prices and acres planted because it:
    - Is domestic in scope and does not account for dampening effects of the global market.
    - Uses an improper baseline.
    - Does not account for the impact of dried distiller grain solubles, which are a byproduct ethanol production and used as an animal feed replacement.
    - Does not account for increasing corn yield and increased ethanol productivity over time.
- Based on the work of Austin et al. (2022), a more realistic simulation modeling study would integrate and evaluate both global and domestic market interactions.
- Taheripour et al. (2022) takes an approach to modeling consistent with the recommendations of Austin et al. (2022).

- For purposes of this report, we accept the following conclusions provided within Taheripour et al. (2022):
    - The bulk of ethanol production prior to 2012 was driven not by the RFS Program, but by the national and global markets for energy and agricultural commodities.
    - Regardless of the drivers, real crop prices have increased between 1.1% and 5.5% from 2004 to 2011 with only one-tenth of the price increases attributable to the RFS Program (i.e., 0.11 to 0.55%).
    - For the period of 2011 to 2016, price impacts of biofuels were less than the period of 2004 to 2011 (i.e., less than 0.11% to 0.55%).
    - Approximately 0.16 million acres (160 thousand acres) of cropland expansion can be attributed to the RFS Program for the period 2011 to 2016, i.e., approximately 1.6% of the 10 million acres of total cropland expansion from all causes assumed by EPA.

- Ramboll modeling efforts indicate that:
    - Based on single variate regression and correlation analysis, the statistical dependency between corn prices and the RFS Program implied conventional volume is either non-existent or very weak.
    - Based on single variate regression and correlation analysis, the statistical dependency between corn prices and ethanol production/consumption is either non-existent or very weak.
    - Based on multi-variate analysis, the implied conventional volume and ethanol production have minimal to no effect on corn prices or corn acres planted.

These results and conclusions presented in Ramboll and Net Gain 2023 *make a strong case for the estimated annual effect of cropland expansion attributed to RFS Program for the years 2008 through 2016* ***to be very close to zero or potentially zero****.*

As part of our work in developing this document, we reviewed the approach EPA uses to obtain the high-end (20%) of its estimated range of cropland expansion attributed to the RFS Program for the years 2008 through 2016, and the literature from which the high-end factors were drawn. The basis of the high-end 20% estimate of cropland expansion is presented in Section 6.3.4 of RtC3.

EPA's method for obtaining the high-end estimate of 20% begins by first obtaining an estimate of the total cropland conversion from all causes. The estimate they obtain for this purpose is the 10.09 million acres reported within Lark et al. (2020). For later percentage calculation, this value is rounded to 10 million acres.

The next step in EPA's process involved estimating how many acres of cropland expansion could be attributed to the RFS Program. EPA accomplishes this by first estimating the highest volume of ethanol production attributed to the RFS Program, as reported in available literature, and then by finding a factor that could be used for converting the high-end ethanol production attributed to the RFS Program into equivalent acres of cropland expansion. This highest volume of corn ethanol production attributed to the RFS in any year is found in Taheripour et al. (2022) at 2.1 billion gallons for the year 2016. To convert this volume into equivalent acres, EPA uses a linear regression coefficient of 0.884 million acres of cropland expansion per billion gallons of ethanol capacity obtained from Li et al. (2019). The multiplication of 2.1 billion gallons times 0.884 million acres per billion gallons results in a high-end estimate of 1.9 million acres of cropland expansion. This value is rounded to 2 million acres of cropland expansion attributed to the RFS Program for purposes of percentage calculation. Thus 2.0 million acres of RFS-attributed cropland expansion divided by 10 million acres of cropland expansion from all causes results in 0.20 or 20%.

Ramboll finds this approach to obtaining the high-end percentage problematic because it:

1. Involves the synthesis of data from several different studies that were performed for reasons other than estimating the acres of cropland expansion attributable to the RFS Program, such as understanding the impact of the RFS Program on crop prices or the effect of ethanol plant proximity on local crop prices and acres planted.
2. Uses a regression coefficient that is based on plant capacity at the county level with a 25-mile radius of influence of bioethanol facilities to estimate total corn cropland expansion of the entire US based on estimated total ethanol production attributable to the RFS Program. This extrapolation is not appropriate because of the difference in units (capacity versus production) and scale (local impact versus total domestic impact) as compared to what the coefficient represents as reported in the underlying study.
3. Uses maximum ethanol production simulation data attributed to the RFS Program from Taheripour et al. (2022) rather than data from the biomass scenario model described in Section 6.4.3 that EPA collaborated with National Renewable Energy Laboratory to develop.
4. Uses the Lark et al. (2020) estimate of total conversion of cropland from all causes when this estimate is known to be questionable due to their reliance on Cropland Data Layer (CDL) data.

We find that EPA's approach is problematic because it synthesizes the highest of high-end factors it could find from all literature, disregarding that each factor was developed using different approaches for different purposes. Our reasons for concern regarding EPA's synthesis of values from various studies will become apparent as we describe each of the studies utilized below.

The primary focus of Taheripour et al. (2022) is on estimating the annual impacts of biofuels production on annual crop price increases. The authors estimate that real crop price increases attributable to the RFS Program for the years 2004 to 2011 are between 0.11% to 0.55%, and that price increases attributable for years 2011 through 2016 are even less. Taheripour et al. (2022) focuses on crop prices because much of the concern regarding the RFS Program is that it induces increased demand for corn, which could in turn cause increased cropland expansion, particularly an increase in acres of corn planted. Although Taheripour et al. (2022) report a high-end value of 2.1 billion gallons attributed to the RFS Program in 2016, for a variety of reasons they attribute only 0.16 million acres (160 thousand acres) of cropland expansion to the RFS Program for the period 2011 to 2016. Therefore, it is inappropriate to use the high-end ethanol production volume provided in Taheripour et al. (2022) to estimate 2.0 million acres of cropland expansion attributable to the RFS Program, a value that is **12.5 times higher** than the number reported in Taheripour et al. (2022).

A more appropriate high-end estimate of total ethanol production attributable to the RFS Program for use in EPA's approach might be found in the work of Newes et al. (2022) as discussed in Section 6.4.3 of RtC3. The biomass scenario model developed by Newes et al. (2022) was created in collaboration with EPA. This system dynamics model allows for the analysis of the impact of non-RFS factors on total annual ethanol production including oil prices, methyl-tertiary butyl ether (MTBE) phase out, Volumetric Ethanol Tax Credit, and octane demand. It also allows for an analysis of the impact of the RFS Program as a function of D6 renewable identification numbers (RINs). The modeling in Newes et al. (2022) finds that the primary drivers for ethanol production through the year 2002 through 2019 are oil prices, MTBE phase out, Volumetric Ethanol Tax Credit, and octane demand. Furthermore, it finds that the incremental effect of D6 RINs on ethanol production is minimal for the years 2002 through 2014 with an increase to approximately 0.5 billion gallons in 2016 and a maximum impact of 1.1 billion gallons in 2018, dropping to approximately 0.25 billion gallons in 2019.

Based on Newes et al. (2022), a more appropriate maximum production value for purposes of EPA's analysis would be 1.1 billion gallons of ethanol production attributable to the RFS Program. This is approximately half of the maximum value reported by Taheripour et al. (2022). Therefore, use of the Newes et al. (2022) maximum ethanol production results would have the effect of reducing the EPA high-end range of 20% cropland expansion due to the RFS Program down to 10%, which is equivalent to 1.0 million acres. Even this 10% value is likely an overestimate due to EPA's inappropriate selection of a regression coefficient, discussed further below. Indeed, it is still 840,000 more acres attributed to the RFS Program than reported by Taheripour et al. (2022) for the period 2011 to 2016. Ramboll does not endorse any replacement high-end value because the correct value is likely close to zero or potentially zero.

We also find the regression coefficient EPA uses problematic because it was obtained from Li et al. (2019), who based the coefficient on plant capacity and not actual ethanol production. Yet EPA uses this coefficient to calculate crop expansion as a function of total ethanol production attributable to the RFS Program.

In addition, the overall goal of the analysis presented in Li et al. (2019) is to estimate the impact of ethanol plant proximity on local crop prices and LUC, i.e., within a 25-mile range of plant location. One of the concepts that Li et al. (2019) was seeking to analyze is that corn acreage expansion would most likely be evident in the vicinity of an ethanol plant because the plant can pay higher corn prices directly to local farmers, due to lower transportation cost, than it could to a terminal market. Their results show that corn acreage is rather inelastic (meaning it increases only to small degree) to changes in both ethanol capacity in the vicinity and crop prices. Even though the results in Li et al. (2019) indicates only a small effect on corn acreage, the effect that they do calculate only pertains to corn acreage near an ethanol plant (i.e., within 25 miles). However, EPA uses the regression coefficient obtained from this study to estimate the total nationwide impact of ethanol production attributed to the RFS on cropland expansion. EPA's extrapolation is not appropriate because of the difference in units (capacity versus production) and scale (local impact versus total domestic impact) than what the coefficient represents as reported in Li et al. (2019).

Lastly, EPA's use of Lark et al. (2020) to estimate the total cropland expansion from all sources is problematic for reasons presented in Section 3.0 regarding the use of the US Department of Agriculture's (USDA's) CDL and summarized in greater detail in Section 4.1 of Ramboll and Net Gain 2023.

Based on this analysis of EPA's approach for obtaining the high-end 20% cropland expansion due to the RFS Program, we conclude that the high-end estimate of 20% is invalid. Throughout many of the analyses in the RtC3, use of this invalid 20% estimate results in substantially overstated high-end estimates of the potential environmental impacts of the RFS Program. Furthermore, we do not suggest a replacement high end value since, based on the results of our work described in Ramboll and Net Gain 2023, a strong case can be made for either no effect or near zero cropland expansion in all years of the RFS Program.

# 3 Chapter 12: Terrestrial Ecosystem Health and Biodiversity

## 3.1 Impacts to Date for the Primary Biofuels

EPA claims that the impacts to date from biofuels on terrestrial biodiversity are "…primarily due to corn and soybean feedstock production…" without sufficient scientific support. Notably, this claim rests largely on disputed analyses that unsuccessfully attempt to link impacts to terrestrial biodiversity with the RFS Program. In EPA's review of scientific literature on possible biofuel feedstock production effects on terrestrial ecosystems, it points out that "The scientific literature was often not specific to the effects of corn and soybeans grown for biofuels…" EPA then proceeds to describe potential impacts from agriculture *in general*, including corn and soybean cultivation, to a set of taxonomic groups and T&E species. EPA presents these potential impacts as primarily resulting from LUC or land cover and land management. EPA does not demonstrate a causal link between impacts to terrestrial biodiversity, on the one hand, and corn and soy production as related to the RFS, on the other.

We urge EPA to clearly state the limitations of previous analyses, as documented by Ramboll and Net Gain (2023). We also urge EPA to acknowledge the lack of clarity on this topic, as demonstrated through its own review of the scientific literature. We suggest these updates be made in the key findings section of this chapter and at the end of the literature review subsection.

### 3.1.1 New Analysis

EPA correctly points out that impacts to terrestrial biodiversity and T&E species hinge on whether (and where) RFS-induced LUC is occurring. However, as previously demonstrated by Ramboll and Net Gain (2023), and detailed in the preceding sections, there is no quantifiable causal link between the RFS and LUC. Thus, in the absence of a quantifiable causal link between the RFS and LUC—and in particular land conversion from grassland, wetland, or forest to corn —there can be no quantifiable causal link between the RFS and impacts to terrestrial species, including T&E species, due to loss or degradation of habitat.

EPA undertook a 'new analysis' in the RtC3 to better understand potential impacts to T&E species specifically. After a review of the analytical methods used, we find that this analysis suffers from the same documented shortcomings (Ramboll and Net Gain 2023) of previous attempts to ascribe a causal link between the RFS and impacts to terrestrial species (see Section 2 above). Notably, the new analysis is based primarily on the work of Lark et al. (2020), which relies on the USDA's CDL, a national-scale data set that has been shown to be too coarse for accurate measurement of LUC (Copenhaver 2022). Investigations into this work have shown that the CDL data layer is unreliable for correctly estimating LUC (Copenhaver 2022; Dunn et al. 2017; Pritsolas and Pearson 2019; Shrestha et al. 2019; USDA 2022), and EPA correctly acknowledges that there can be differences in land cover classifications at the field scale from data derived from remote sensing products (i.e., CDL). To illustrate this, Shrestha et al. (2019) compared CDL-derived land conversion (i.e. from perennial cover to cropland) to manually verified land conversion and found **less than 4% agreement**. Despite this, EPA attempts to validate the estimates of conversion from Lark et al. (2020) by comparing the CDL against a second remote sensing-derived product based on LANDSAT, which features the same spatial resolution (30 meters) as the CDL. This resolution has also been shown to lack sufficient granularity to observe change in small plots of land (Copenhaver 2022). Neither of these datasets is appropriate for use as the basis for estimating RFS-driven LUC.

EPA's new analysis produces a list of 27 terrestrial T&E species that have experienced an estimated 10 acres or more of conversion of land (hereafter "$\geq$10-acre threshold") in perennial cover to corn (or soy) within a 1-mile buffer of its US Fish and Wildlife Service (USFWS)-designated critical habitat (Table

12.2). Of the 27 species identified, 6 are said to have experienced some amount (i.e., a portion of EPA's >10-acre threshold) LUC within their critical habitat [RtC3 Executive Summary, lines 490-494]. Again, we point to the documented deficiencies regarding use of nationally-scaled datasets to assess field level LUC, and EPA's own acknowledgment that direct visitation may be necessary to confirm these results (RtC3 at lines 447-449). We recommend that EPA acknowledge that the >10-acre threshold and 1-mile buffer criteria are arbitrary, and their relevance varies depending on the species being addressed. We make this recommendation because the EPA has provided no scientific basis for using either the >10-acre threshold or the 1-mile buffer criteria. We inferred that EPA is assuming that if their model, which is based on LUC estimates derived from the USDA CDL, shows >10 acres of LUC within 1 mile of critical habitat, then sufficient LUC to have negatively affected T&E species must have occurred. However, critical habitat is the specific area that contains the physical and/or biological features that are essential to the conservation of T&E species (USFWS 2017). Thus, the application of a 1-mile buffer to designated critical habitat is unwarranted because these buffer areas typically do not provide the resources needed to sustain populations of T&E species. This methodology artificially inflates the list presented in Table 12.2 from the 6 species with overlapping critical habitat and modeled LUC, to 27 species. Lastly, this analysis is only relevant with respect to the RFS if EPA can demonstrate that a quantifiable percentage of LUC in these areas is attributable to the RFS Program. However, as we have clearly shown in Section 2 of this document, RFS-attributable LUC is more likely close to zero. Thus, the impact to T&E species which can be attributed to the RFS is also likely close to zero.

Furthermore, EPA fails to acknowledge that even if LUC is occurring within 1 mile of or inside critical habitat, the potential for species impacts is unclear without additional analysis. For example, no consideration was given to species-specific life history, habitat preferences, seasonality, population trends, possible recovery, or historic versus current threats (see below). Other than the application of the arbitrary criteria for proximity of corn (and soy) fields mentioned above, EPA presents no technical assessment of the actual risk to these species. In the absence of scientific support that risk to a particular species is related to the RFS Program, EPA should remove extraneous discussion of general environmental effects which may mislead the reader. At a minimum, this section needs to be qualified as speculative and theoretical, and appropriate statements need to be included regarding what additional study is needed to adequately estimate risks associated with the RFS.

Finally, though not cited in this draft RtC3, a recent analysis of potential interactions between the RFS and the Endangered Species Act attempts to establish a spatial relationship between RFS-induced LUC by overlaying the critical habitat and endangered range of three federally-listed species with a cropland conversion layer based on the CDL (Lark 2023). Upon examination of the figures intended to illustrate this critical overlap, Lark (2023) demonstrates for all highlighted species, that the spatial relationship between critical habitat and areas potentially experiencing the most LUC **is weak or non-existent**.

#### 3.1.1.1 Whooping Crane (*Grus americana*)

EPA claims that the decline of the whooping crane (*Grus americana*) is primarily due to the loss of the grassland and wetland habitats the species depends on, which was caused by historical expansion of agricultural lands. Although this species was nearly extirpated by the 1940s, EPA states that habitat loss is still ongoing, particularly within the cranes' migratory corridor. Notably, however, agriculture is not among the key current stressors identified by the USFWS (2011) or the International Union for the Conservation of Nature (Smith 2019), and EPA fails to mention that significant conservation measures have helped to increase the whooping crane population (Smith 2019). Since 1996, the total number of whooping cranes in the wild has increased from 205 to about 604, with considerable growth in the Aransas-Wood Buffalo population (Smith 2019), the same population that uses the American Midwest as a migratory corridor. Of note, the population of wild whooping cranes has steadily grown with no dip apparent after the implementation of the RFS (Figure 1). In fact, after 2007, the population of whooping cranes appears to have increased even faster than it did between 1990 and 2007 (Figure 1). While EPA does acknowledge that possible impacts to this species stem from agriculture in general rather than specifically from the RFS Program, we nonetheless strongly recommend that EPA further acknowledge the lack of a quantitative nexus between the RFS and possible impacts to this species.

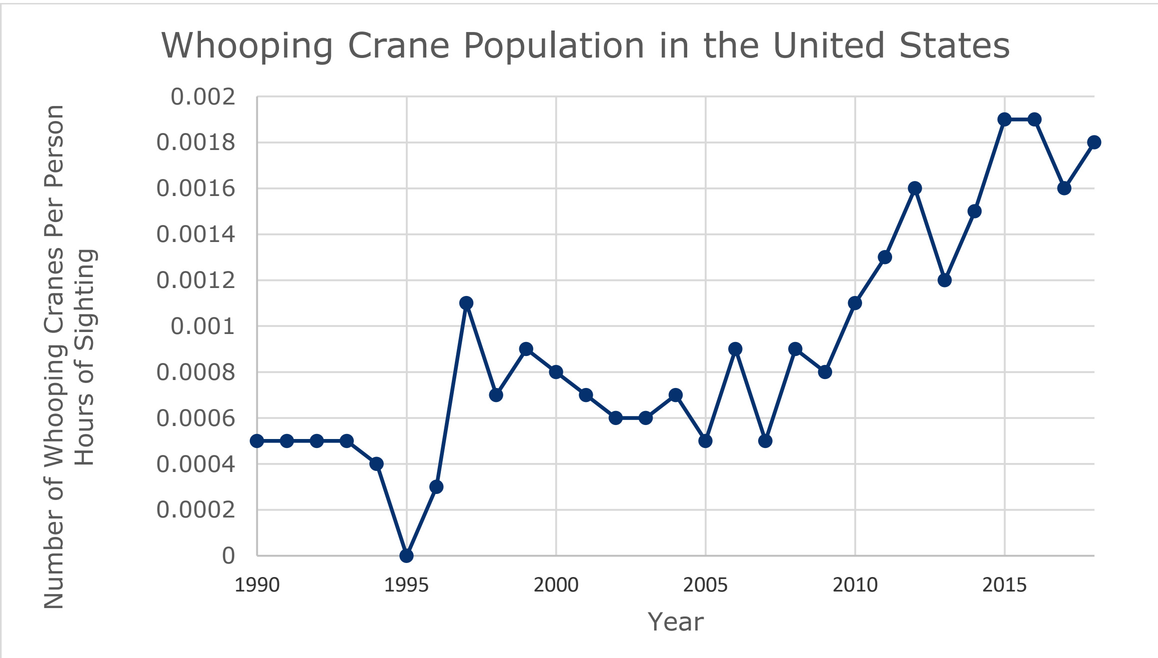



**Figure 1: United States Whooping Crane Population, 1990 to 2018. Data are from the Audubon Society's Christmas Bird Count Database (Audubon 2023) and are shown here by the number of cranes per person hour of observation time.**

### 3.1.1.2 Poweshiek Skipperling (*Oarisma poweshiek*)

EPA claims that the decline of the Poweshiek skipperling (*Oarisma poweshiek*) is primarily due to loss of plant biodiversity and fragmentation of native tallgrass prairie, which was caused by a loss of habitat attributable to land conversion. Again, EPA's discussion of impacts is limited to those caused by agriculture in general and cannot be causally attributed to the RFS Program. In fact, loss of tallgrass prairie within the former range of this species began in the early 1800s, and by the mid-1990s nearly all of this habitat had been lost to agriculture in Minnesota, Iowa, North and South Dakota, Illinois, Indiana, and Wisconsin (Delphey et al. 2016). Throughout much of the Midwest, the last observations of adults of this species occurred in 2008. Given this timeline, land conversion to agriculture extirpated this species from the vast majority of its range 10 years or more before the RFS could have had any impact. For this reason, we strongly recommend that EPA acknowledge that while agriculture in general likely had an impact on this species historically, the implication that land conversion spurred by the RFS has adversely impacted critical habitat of the Poweshiek skipperling is unsubstantiated.

### 3.1.1.3 Indiana Bat (*Myotis sodalis*)

The Indiana bat (*Myotis sodalis*) is a small, insectivorous migratory bat that was once abundant in forested areas in the eastern half of the US. *M. sodalis* hibernates colonially and is restricted to underground hibernacula, including caves and mines, during the winter months. In summer this species occupies forests where it often roosts beneath the exfoliating bark of dead or dying trees. The Indiana bat was listed as endangered in 1966. While agriculture may have played a role in its initial decline, current threats to this species include climate change, proliferation of invasive species, wind turbines, disturbance to hibernacula, and white nose syndrome (WNS), a fungal pathogen that is considered one of the worst wildlife diseases in modern times (USFWS 2019). Since the discovery of WNS in the winter of 2007, millions of bats have died, causing an estimated 90% decline in hibernating bat populations within the WNS-affected area (USFWS 2019).

As previously demonstrated (Ramboll and Net Gain 2023) and detailed in the preceding sections, the RFS has not contributed significantly to LUC, particularly with respect to forest conversion, the primary summer habitat for this species. Further, since 2007, which was the first year of the RFS Program, the most significant threat to the Indiana bat and other bat species has been WNS. For these reasons, and those detailed above with respect to the other highlighted species, we recommend that EPA include additional columns in Table 12.2, or additional discussion, to reflect current population trends and to acknowledge that current threats stem from factors other than LUC.

#### 3.1.2 Attribution to the RFS

EPA concludes that a range of 0-20% of the net increase in US crop area is attributable to the RFS Program between 2008 and 2016, and correctly notes that if the RFS Program did not cause LUC from perennial cover to additional corn or soybean acres, then the RFS Program likely had no effect on biodiversity (RtC3 Chapter 12, lines 499–504). EPA recognizes that RFS-induced impacts to terrestrial T&E species are even harder to define, noting that even if up to 20% of total LUC was attributable to the RFS, RFS-attributable conversion may not have occurred within the designated critical habitat of these species. We have shown previously (Ramboll and Net Gain 2023), and above, that the RFS likely contributed very little to total LUC, and thus very little to potential impacts to terrestrial biodiversity and T&E species. For these reasons, we recommend EPA include qualifying statements in the key findings, literature review, and new analysis sections of Chapter 12 that emphasize the inability to causally link the RFS with impacts to terrestrial biodiversity and T&E species.

## 4 Chapter 13: Aquatic Ecosystem Health and Biodiversity

### 4.1 Impacts to Date for the Primary Biofuels

In presenting the results of a literature review of potential impacts to aquatic ecosystems from biofuel feedstock production, EPA notes that "…the literature was not specific enough in most cases to address the effects of corn and soybeans grown for biofuels, let alone any potential changes from the RFS Program…" (page 13-7, lines 172-174). We agree with this statement. The remainder of this section of the report summarizes the results of the literature review in terms of the general effects of corn and soybean cultivation including potential effect from flow alterations, nutrient and sediment inputs, and pesticides on fish, invertebrates, plants, algae, and other organisms, and presents a discussion of harmful algae blooms. The fact that there is not a demonstrated nexus between such impacts and corn and soy related to increased demand from the RFS is lost in EPA's lengthy generic descriptions of potential impacts from agriculture. We urge EPA to add the limitation stated above to the key findings section of this chapter as well as repeating it at the end of the literature review subsection.

### 4.2 New Analyses: SWAT Modeling and Nutrient Thresholds

EPA presents results of the application of the Soil and Water Assessment Tool (SWAT) modeling to the Missouri River Basin (MORB). Changes in conditions over the period 2008 to 2016 were modeled under three conversion scenarios: baseline, continuous corn, corn/soy rotation, and corn/wheat rotation.

Pesticides were not modeled. The modeling revealed no meaningful changes in streamflow and sediment inputs, but it did result in predicted increases in nutrient inputs. The discussion in the report, however, fails to mention that the analysis presented draws no conclusions whatever regarding the potential effect of the RFS Program, and that it is based on three change scenarios applied uniformly across the basin. These limiting factors need to be explicitly acknowledged up front in the text. Despite the very conservative nature of its analysis, EPA concludes that "… the watersheds in the MORB are already significantly affected by nutrients, and the additional strain from changes from 2008-2016 are difficult to separate from the baseline conditions" (page 13-33, lines 748-750). EPA further notes that "…all states for which there are numeric nutrient criteria already have TN and TP exceedances, even without the small increases due to the scenarios examined" (page 13-36, lines 764-765). The overall conclusions from this modeling exercise should be clearly stated as follows: The modeling exercise is based on conservative assumptions regarding LUC and cropping practices and does not attempt to estimate the likely small or non-existent effect of the RFS on the change modeled. Further, the SWAT modeling shows that biofuels feedstock production in the Missouri River Basin does not affect streamflow and sediment input and has an inconsequential effect on exceedance of water quality criteria for TN and TP where these criteria exist.

### 4.3 Aquatic T&E Species

EPA rightfully acknowledges the high level of uncertainty associated with establishing a quantitative causal link between increased demand for corn grown for ethanol due to the RFS and potential impacts to water quality and aquatic habitat that may adversely impact T&E species. At Table 12.1, the document identifies 78 aquatic T&E species whose critical habitat is within 1 mile of 10 or more acres of land converted to corn or soy. As with terrestrial T&E species, EPA provides no support for utilizing these thresholds for aquatic species.

First, EPA should acknowledge that these proximity criteria are arbitrary, and their relevance varies depending on the species being addressed. In particular, these criteria may be irrelevant for assessing risk to aquatic species for two principal reasons: 1) corn and soy are not aquatic plants and their cultivation will therefore not result in the conversion of any aquatic habitat, and 2) potential water quality effects from sheet runoff from agricultural fields are generally expected to decrease rapidly with distance from a water body and may well approach zero at a distance of 1 mile. For example, no consideration was given to species-specific life history, habitat preferences, seasonality, population trends, possible recovery, or historic versus current threats. Irrespective of the arbitrary nature of these criteria, the text of the document merely discusses pathways for impacts to aquatic species from agricultural practices in general. As is the case with the terrestrial assessment, EPA presents no technical assessment of the actual risk to these species. This general discussion creates the impression of a causal link, without providing any substantive analysis. Although the document acknowledges that potential impacts (e.g., to water quality) may be minor, it then states that such impacts may be occurring in water bodies that are already stressed for reasons not associated with corn for ethanol (e.g., page 13-41, lines 864-868). This statement implies some "tipping point" and that such a tipping point may be breached due to the RFS. This statement lacks sufficient justification and should be properly qualified as theoretical and solely for the purposes of discussing risk, not documenting impacts.

For selected species, the report discusses potential impacts in general, some of which are clearly not associated with the RFS (see discussion below) or corn grown for ethanol. EPA should remove discussion of species impacts that are not related to the RFS and, at a minimum, should qualify this section as speculative and theoretical.

#### 4.3.1 Topeka Shiner (*Notropsis topeka*)

EPA identifies that the principal reason for impacts to the habitat of the Topeka shiner is removal of sediment from river oxbows to restore groundwater connections. The report then goes on to mention the potential role of atrazine in reducing prey items for this species and mentions that atrazine has been implicated as having adverse effects on 33 other T&E fish species. However, EPA presents no further assessment of this potential effect and provides no evidence that such an adverse effect is in any way linked to the RFS Program.

The Center for Biological Diversity (2023) mentions the following threats to this species: dams that alter stream flow, prevent fish passage, and subject the fish to greater predation; gravel-removal operations; water pollution from livestock; and land-use changes resulting from urbanization. We urge EPA to edit the text in this section to accurately reflect the primary stressors on this species and acknowledge the lack of a quantitative nexus between the RFS and any potential impacts of atrazine on this species and the other 33 species listed in table 13.4.

EPA also fails to acknowledge that in its latest 5-year review, USFWS (2021) recommended reclassification of this species from endangered to threatened due to improvements in its population status resulting from habitat restoration actions.

#### 4.3.2 Arkansas River shiner (*Notropsis girardi*)

EPA identifies "a variety of physical and chemical factors" (page 13-17, lines 799-801) that have been associated with the declining range of this species including reduced stream flow, warmer temperature, and increases in total and dissolved solids but provides no discussion of how these factors may or may not be related to the RFS. The most recent 5-year review for this species notes the following primary stressors: altered flow regimes, impoundments and other stream fragmentation, modified geomorphology, decreased water quality, and the introduction of invasive species (USFWS 2020). The 5-year review also states that the source of many of these stressors is related to the construction of dams and their impoundments. We urge EPA to edit the text in this section to acknowledge the importance of stressors that are clearly not related to the RFS as well as the lack of a quantitative nexus between the RFS and potential impacts to this species.

#### 4.3.3 Gulf Sturgeon

EPA's discussion of Gulf sturgeon focuses on the presence and severity of the annual formation of a large hypoxic zone in the GoM often called the "GoM dead zone" and completely ignores the main factors affecting this species as documented in the most recent 5-year review: construction of dams on the Pearl, Alabama and Apalachicola Rivers and St. Andrews Bay; channel improvement and maintenance activities (dredging and snagging), and localized water quality degradation, and contaminants (USFWS and National Marine Fisheries Service 2022). The 5-year review does not mention the GoM dead zone and only mentions hypoxia as it relates to stormwater runoff and general life history requirement for the species. The only mention of agriculture in the 5-year review is related to critical habitat degradation in the upper Choctawhatchee and lower Pea Rivers.

By discussing the GoM dead zone in the RtC3, EPA implies that its formation is related to increased nutrient inputs to the Mississippi River basin due to the RFS. This implication is misleading for a variety of reasons, including the fact that the dead zone was forming on a regular basis long before the enactment of the Energy Independence and Security Act and any potential impacts from the RFS. EPA presents no quantitative assessment of the effect on the dead zone from any potential increase in nutrient inputs attributable to the RFS. Furthermore, EPA fails to recognize that TN loading to the GoM has been decreasing, including over the period of increased use of corn for ethanol (see Figure 2). EPA

(2022) concludes that the flow-normalized TN loads decreased 16% between the baseline period of 1980–1996 and 2019 and that almost all of that decrease was due to reductions in upstream nitrogen sources. Thus, there is no support for the assertion of a causal relationship between ethanol production and the GoM dead zone (see discussion presented in Ramboll 2019 for more information), and even less for a relationship between the RFS Program and the GoM dead zone.

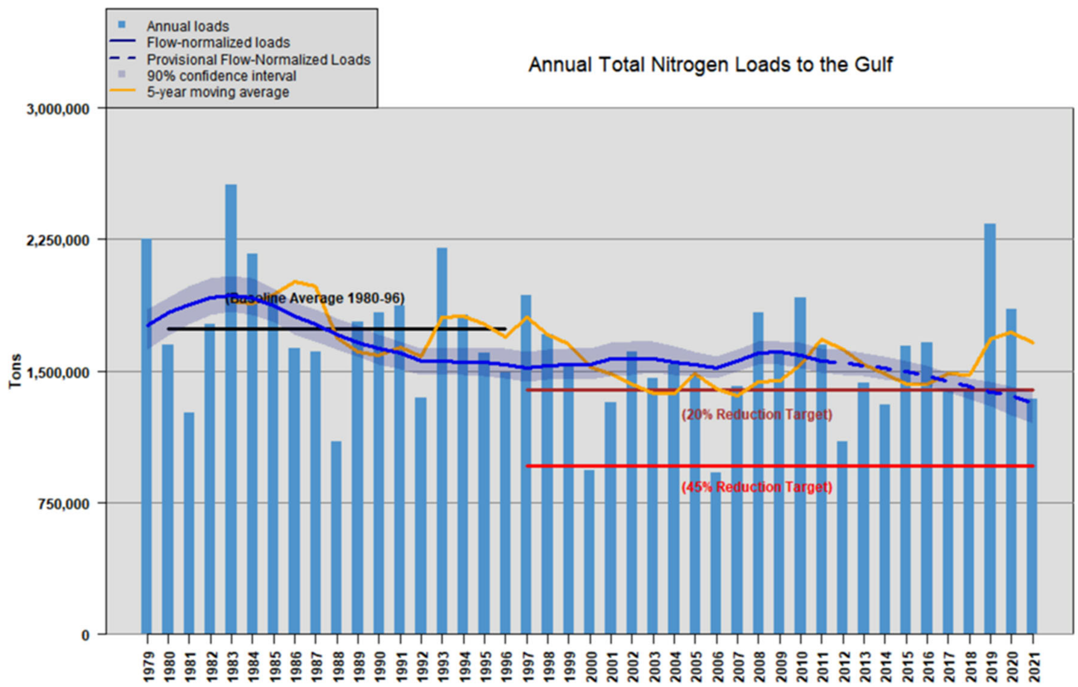



**Figure 2: Total Nitrogen Loads to the Gulf of Mexico from the Mississippi River and Atchafalaya River 1980 to 2021. Source: US Geological Survey 2021**

Similar to its Second Triennial Report, EPA also completely fails to acknowledge the geographical disconnect between critical habitat for the Gulf sturgeon and the occurrence of the dead zone in the GoM. The dead zone forms west of the Mississippi River Delta over the continental shelf (<200 meters in water depth) of Louisiana and sometimes extends westward to Texas. Figure 3 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. The National Oceanic and Atmospheric Administration's (NOAA's) Gulf of Mexico Hypoxia Watch site presents results from dissolved oxygen monitoring for the period 2001 to 2021.

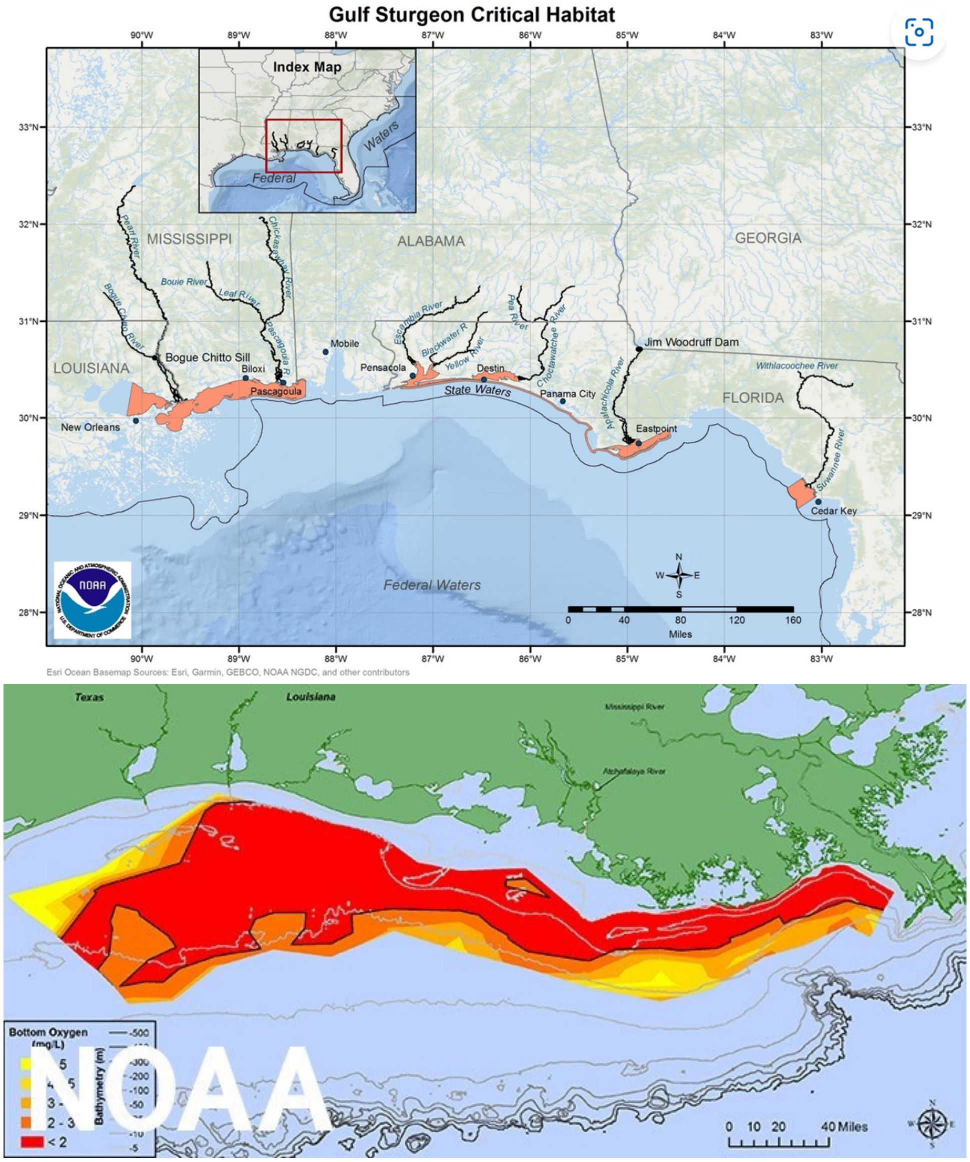



**Figure 3: Location of Critical Habitat for Gulf Sturgeon and Extent of the Gulf of Mexico "Dead Zone" in 1991. Sources: NOAA 2017; NOAA Fisheries 2022**

These results show that hypoxia rarely extends near critical habitat for Gulf sturgeon and when it does, it is 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. Further, EPA acknowledges that "The timing of spring migration does not typically coincide with HABs [harmful algal blooms] or the onset of the dead zone in the Gulf of Mexico, which are usually summer or late-summer phenomena" (page 13-38, lines 807-809).

In conclusion, the lack of temporal and geographic association between the GoM hypoxic zone and critical habitat and use of that habitat by Gulf sturgeon suggests no potential impact to this endangered species from the GoM dead zone. Furthermore, the potential effect of the RFS on the size and severity of the GoM hypoxic zone has not been demonstrated and is likely to be vanishingly small, especially when compared to other important factors such as weather and the historically extensive sink of nutrients that is trapped in sediment and is mobilized as the sediment continually moves down the Mississippi River. For the reasons stated above, this section is misleading. EPA should expand the discussion in this section to provide a realistic presentation of threats to this species and should acknowledge the lack of any demonstrated nexus between the RFS Program and the GoM dead zone.

#### 4.3.4 Mollusks

In the brief section on mollusks in the RtC3, EPA simply describes factors influencing the decline in mollusk populations and includes a study citing a negative association between mussel growth rates and row crops in Kentucky rivers. The section also cites Supplemental Table 13.4 that lists 8 mussel species whose habitats are likely adversely affected by atrazine. USFWS lists entries for 124 freshwater mussel species, 90 of which are either endangered or threatened (USFWS 2023). The listed species have wide-ranging geographies with many being far removed from most corn growing regions in general, and in particular, no association with areas experiencing extensification for biofuels crops since 2008. Any discussion that does not start by focusing on species potentially affected by corn extensification is misleading.

In this section, EPA presents no discussion of whether or how these observations are related to the RFS. Most important, it is widely documented by USFWS, many state agencies, and numerous non-governmental conservation organizations that the biggest threat to this taxonomic group is loss of habitat from dams and channelization of waterways affecting natural hydrological regimes, with lesser threat from degraded water quality. The RtC3 report specifically mentions pink mucket (*Lampsilis abrupta*) as an example of the pearly mussels group that requires larval host fish to complete their reproductive cycle. The reason for mentioning this species or species assemblage is unclear, as there is no indication of any linkage between the RFS Program and impacts to host fish populations.
The historical range of the pink mucket includes rivers in Alabama, Arkansas, Illinois, Indiana, Kentucky, Louisiana, Missouri, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia. The most recent 5-year review on the pink mucket includes a discussion of threats to the species and this discussion focuses on habitat degradation due to physical alterations to hydrology, primarily from impoundments (USFWS 2018). The 5-year review goes on to document that the primary threats to extant populations are navigation activities, releases from reservoirs, mining activities, inadequate treatment of wastewater discharges, and factors related to disjunct populations. There is no mention of agriculture in the 5-year review. We urge EPA to add text that places the general discussion in the proper context especially regarding the relative importance of stressors and lack of geographical nexus for many species. In addition, EPA should acknowledge that there is no evidence that RFS-related biofuels crops are adversely affecting T&E mollusks.

### 4.4 Attribution to the RFS

EPA concludes that "…the effects from the RFS Program on aquatic ecosystems from the expansion of cropland alone may be up to approximately 0–20% of the results presented in section 13.3.2." (page 13-40, lines 856-858). This statement should be removed from the text because it is not supported by the preceding discussion. Other than presenting modeled water quality results for certain water bodies in agricultural areas, EPA did not document effects attributable to corn/soy in Section 13.3.2.

# 5 Chapter 14: Wetland Ecosystem Health and Biodiversity

## 5.1 Impacts to Date for the Primary Biofuels

EPA's discussion of potential wetland impacts is subject to the same points of criticism as outlined in the previous sections of this memo. For that reason, the next section is limited to discussion of wetland obligate T&E species and RFS attribution.

### 5.1.1 Wetland Obligate T&E Species

In this section of the RtC3, EPA points to the 'new analysis' described in Chapter 12 of the RtC3, and identifies a selection of wetland obligate species that may be impacted by the conversion of wetlands to cropland. As outlined in our review of Chapter 12 (Section 3), EPA's approach -- which includes a reliance on cropland conversion data produced by Lark et al. (2020), the assignment of arbitrary proximity criteria, and lack of species-specific consideration -- makes this analysis cursory at best, and it lacks the depth needed to attribute species-level impacts to any particular cause, including the RFS Program.

The list of species highlighted in this brief section of the RtC3 includes the whooping crane, multiple bat species, one insect, one reptile, and the piping plover. As we've detailed in our Chapter 12 review, the whooping crane population is steadily increasing, particularly within the population that traverses the American Midwest during annual migration. Of the five bat species identified, three are not federally-listed threatened or endangered species (red bat [*Lasiurus borealis*], hoary bat [*Lasiurus cinereus*], silver-haired bat [*Lasionycteris noctivagans*]), and should be removed from this discussion and Table 12.2. The remaining two bat species (northern long-eared bat [*Myotis septentrionalis*] and little brown bat [*Myotis lucifugus*]), have suffered significant population declines due to WNS since 2007 when this fungal pathogen was first observed, and are not wetland obligate species. EPA should remove the discussion of these species from this section.

### 5.1.2 Piping plover (*Charadrius melodus*)

The piping plover is a migratory shorebird that nests and forages along coastal sand and gravel beaches in North America. The piping plover population on the Great Lakes is listed as endangered, whereas populations in the Northern Great Plains and Atlantic coast are listed as threatened. Current threats afflicting these populations include coastal beach habitat loss due to commercial, residential, and recreational developments; effects of water control structures on nesting habitat; vehicle and pedestrian use of beaches; harassment or mortality of birds by pets; and predation. While LUC resulting from urban development was listed as a potential threat (Cohen et al. 2009), LUC due to agriculture is not recognized as a significant threat to these populations.

For these reasons, and those detailed above with respect to the other highlighted species, we recommend that EPA include additional columns in RtC3 Table 12.2, or additional discussion, to accurately reflect current population trends and threats. Additionally, we urge EPA to review the list of species they have provided in Table 12.2 and remove any species that are not a federally-listed threatened or endangered species.

### 5.1.3 Attribution to the RFS Program

EPA's attribution of wetland impacts to the RFS Program is based largely on the work of Lark et al. (2020) which, for reasons documented above, has been shown to be an inaccurate and unreliable assessment of RFS LUC. As noted in Chapter 12 of the RtC3, the presence and magnitude of RFS impacts depend on whether and where RFS-induced LUC is occurring; and since EPA's own reported range of the net increase in US crop area that may be attributed to the RFS includes zero (0 to 20%), any wetland impacts attributed to the RFS are unsubstantiated. As we have shown previously (Ramboll and Net Gain 2023), and above, the RFS likely contributed very little to total LUC, and thus very little to potential wetland impacts from LUC. We urge EPA to make this clear throughout Chapter 14 while also noting more effectively that impacts to wetlands, as discussed in this chapter, are focused on the general impacts of agriculture that "can only be evaluated in the context of widespread historical losses" (as noted in the background section), not the RFS.

This is particularly important in the key findings section where EPA presents wetland losses caused by cropland expansion between 2008 and 2016, which are inferences based largely on the disputed work of Lark et al. (2020). According to EPA, cropland expansion during this time resulted in the conversion of nearly 275,000 acres of wetlands concentrated in the Prairie Pothole Region. While EPA acknowledges that the extent of wetland losses that can be directly attributed to the RFS "cannot be more accurately estimated" (page 14-34, lines 978-980), this implies that the full 3% conversion is attributable to the RFS. For this reason, we recommend modifying lines 978-980 to clearly address the inability to attribute wetland losses to the RFS, as follows: "Given the lack of national or regional datasets to track changes in RFS-attributable acreage, wetland acreage losses cannot be attributed to the RFS at this time."

## 6 References

Audubon. 2023. Audubon's Christmas Bird Count Results. [accessed 2023 Feb 15]. https://netapp.audubon.org/CBCObservation/.

Austin KG, Jones JPH, Clark CM. 2022. A review of domestic land use change attributable to U.S. biofuel policy. Renewable and Sustainable Energy Reviews. 159:Article 112181. doi:10.1016/j.rser.2022.112181.

Center for Biological Diversity. 2023. Topeka shiner. [accessed 2023 Feb 28]. https://www.biologicaldiversity.org/species/fish/Topeka_shiner/index.html.

Cohen JB, Houghton LM, Fraser JD. 2009. Nesting density and reproductive success of piping plovers in response to storm- and human-created habitat changes. Wildlife Monographs. 173(1):1–24. doi:10.2193/2007-553.

Copenhaver KL. 2022. Combining tabular and satellite-based datasets to better understand cropland change. Land. 11(5):714. doi:10.3390/land11050714.

Delphey P, Runquist E, Harris T, Nordmeyer C, Smith T, Traylor-Holzer K, Miller PS. 2015. Poweshiek Skipperling, Dakota Skipper: *Ex Situ* Feasibility Assessment and Planning Workshop. Workshop Report. Apple Valley, MN: IUNC/SSC Conservation Breeding Specialist Group.

Dunn JB, Merz D, Copenhaver KL, Mueller S. 2017. Measured extent of agricultural expansion depends on analysis technique. Biofuels, Bioproducts and Biorefining. 11(2):247–257. doi:10.1002/bbb.1750.

EPA. 2011. Biofuels and the Environment: First Triennial Report to Congress. December. Report No.: EPA/600/R-10/183F.

EPA. 2018. Biofuels and the Environment: Second Triennial Report to Congress. Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development. Report No.: EPA/600/R-18/195F. June. https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=IO&dirEntryId=341491.

EPA. 2022. Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, 2019/2021 Report to Congress. March. https://www.epa.gov/system/files/documents/2022-02/hypoxia_task_force_report_to_congress_2019_21_final.pdf.

Lark TJ. 2023. Interactions between U.S. biofuels policy and the Endangered Species Act. Biological Conservation. 279:Article 109869. doi:10.1016/j.biocon.2022.109869.

Lark TJ, Hendricks NP, Smith A, Pates N, Spawn-Lee SA, Bougie M, Booth EG, Kucharik CJ, Gibbs HK. 2022. Environmental outcomes of the US Renewable Fuel Standard. Proceedings of the National Academy of Sciences. 119(9):Article e2101084119. doi:10.1073/pnas.2101084119.

Lark TJ, Mueller RM, Johnson DM, Gibbs HK. 2017. Measuring land-use and land-cover change using the U.S. department of agriculture's cropland data layer: Cautions and recommendations. International Journal of Applied Earth Observation and Geoinformation. 62:224–235. doi:10.1016/j.jag.2017.06.007.

Lark TJ, Spawn SA, Bougie M, Gibbs HK. 2020. Cropland expansion in the United States produces marginal yields at high costs to wildlife. Nature Communications. 11(1):Article 4295. doi:10.1038/s41467-020-18045-z.

Li Y, Miao R, Khanna M. 2019. Effects of ethanol plant proximity and crop prices on land-use change in the United States. American Journal of Agricultural Economics. 101(2):467–491. doi:10.1093/ajae/aay080.

Newes E, Clark CM, Vimmerstedt L, Peterson S, Burkholder D, Korotney D, Inman D. 2022. Ethanol production in the United States: The roles of policy, price, and demand. Energy Policy. 161:Article 112713. doi:10.1016/j.enpol.2021.112713.

NOAA. 2017. Gulf of Mexico 'Dead Zone' Is the Largest Ever Measured. August 2. https://www.noaa.gov/media-release/gulf-of-mexico-dead-zone-is-largest-ever-measured.

NOAA Fisheries. 2022. Gulf Sturgeon Critical Habitat Map and GIS Data. [accessed 2023 Feb 28]. https://www.fisheries.noaa.gov/resource/map/gulf-sturgeon-critical-habitat-map-and-gis-data.

Pritsolas J, Pearson R. 2019. Critical Review of Supporting Literature on Land Use Change in the EPA's Second Triennial Report to Congress. Prepared for Renewable Fuels Association.

Ramboll. 2019. The RFS and Ethanol Production: Lack of Proven Impacts to Land and Water. Prepared for Growth Energy by Ramboll. August 18.

Ramboll, Net Gain. 2023. Review of Environmental Effects and Economic Analysis of Corn Prices: EPA's Proposed RFS Standards for 2023-2025. Ramboll US Consulting, Inc. and Net Gain Ecological Services. February.

Shrestha DS, Staab BD, Duffield JA. 2019. Biofuel impact on food prices index and land use change. Biomass and Bioenergy. 124:43–53. doi:10.1016/j.biombioe.2019.03.003.

Smith E. 2019. Species Review: Whooping Crane (*Grus americana*). IUCN SSC Crane Specialist Group – Crane Conservation Strategy. Baraboo, WI: International Crane Foundation.

Taheripour F, Baumes H, Tyner WE. 2022. Economic impacts of the U.S. Renewable Fuel Standard: An ex-post evaluation. Frontiers in Energy Research. 10:Article 749738. doi:10.3389/fenrg.2022.749738.

US Geological Survey. 2021. Trends in Annual Water-Quality Loads to the Gulf of Mexico. [accessed 2023 Jan 12]. https://nrtwq.usgs.gov/nwqn/#/GULF.

USDA. 2022. Technical Memorandum: Review of Recent PNAS Publication on GHG Impacts of Corn Ethanol. United States Department of Agriculture, Office of the Chief Economist, Office of Energy and

Environmental Policy. December 14. https://www.usda.gov/sites/default/files/documents/USDA-OCE-Review-of-Lark-2022-For-Submission.pdf.

USFWS. 2011. Whooping Crane (*Grus americana*) 5-Year Review: Summary and Evaluation. United States Fish and Wildlife Service, Aransas National Wildlife Refuge, and Corpus Christi Ecological Service Field Office.

USFWS. 2017. Critical Habitat Fact Sheet. USFWS Endangered Species Program. Falls Church, VA. March.

USFWS. 2018. Pink Mucket (*Lampsilis abrupta*) 5-Year Review: Summary and Evaluation. United States Fish and Wildlife Service, Asheville Field Office. April.

USFWS. 2019. Indiana Bat (*Myotis sodalis*) 5-Year Review: Summary and Evaluation. Bloomington, IN: United States Fish and Wildlife Service, Indiana Ecological Services Field Office. September.

USFWS. 2020. Arkansas River Shiner (*Netropsis girardi*) 5-Year Review: Summary and Evaluation. Tulsa, OK: United States Fish and Wildlife Service, Oklahoma Ecological Services Field Office. September 28.

USFWS. 2021. Topeka Shiner (*Notropsis topeka*) 5-Year Status Review: Summary and Evaluation. Denver, CO: United States Fish and Wildlife Service, Interior Regions 5 and 7.

USFWS. 2023. FWS-Listed U.S. Species by Taxonomic Group - Clams. [accessed 2023 Feb 28]. https://ecos.fws.gov/ecp/report/species-listings-by-tax-group?statusCategory=Listed&groupName=Clams&total=123.

USFWS, National Marine Fisheries Service. 2022. Gulf Sturgeon (*Acipenser oxyrinchus desotoi*) 5-Year Review: Summary and Evaluation. United States Fish and Wildlife Service, Panama City Fish and Wildlife Conservation Office and National Marine Fisheries Service, Southeast Region Protected Resources Division. February.

**Growth Energy Comments on "Biofuels and the Environment: Third Triennial Report to Congress (External Review Draft)"**

Docket ID No. EPA–HQ–ORD–2020–0682

# Exhibit 2

ENVIRONMENT
& HEALTH

# REVIEW OF ENVIRONMENTAL EFFECTS AND ECONOMIC ANALYSIS OF CORN PRICES: EPA'S PROPOSED RFS STANDARDS FOR 2023-2025

Prepared at the Request:
**Growth Energy**

Prepared By:
**Ramboll and Net Gain Ecological Services**

Date:
**February 2023**

RAMBOLL

## Contents

| | | |
|---|---|---|
| 1. | Executive Summary | 1 |
| 1.1 | Economic Analysis | 1 |
| 1.2 | Land Use Change | 4 |
| 1.3 | Soil and Water Quality | 5 |
| 1.4 | Water Quantity and Availability | 5 |
| 2. | Introduction | 6 |
| 3. | Economic Analysis | 7 |
| 3.1 | Complexities in Modeling the Effect of the RFS on Corn Prices and Acres Planted | 8 |
| 3.2 | Economic Literature Review | 11 |
| 3.2.1 | Lark et al. (2022) | 12 |
| 3.2.2 | Austin et al. (2022) | 16 |
| 3.2.3 | Taheripour et al. (2022a) | 17 |
| 3.2.4 | EPA DRIA (2022b) | 18 |
| 3.3 | Economic Analysis Methodology | 19 |
| 3.3.1 | Variables of Ethanol Industry | 19 |
| 3.3.2 | Analysis Objectives | 20 |
| 3.3.3 | Economic Analysis | 21 |
| 3.4 | Economic Results/Discussion | 33 |
| 4. | Environmental and Ecological Analysis | 33 |
| 4.1 | Land Use Change References | 34 |
| 4.2 | Conversion of Wetlands, Ecosystems, and Wildlife Habitats | 36 |
| 4.2.1 | Wetlands | 37 |
| 4.2.2 | Other Ecosystems | 37 |
| 4.2.3 | Wildlife | 38 |
| 5. | Soil and Water Quality | 40 |
| 6. | Water Quantity and Availability | 43 |
| 6.1 | Impact of Corn Production on the HPA | 44 |
| 6.2 | Other Factors Affecting the HPA | 47 |
| 6.3 | Advanced Agriculture and Reduction in Water Use | 47 |
| 6.4 | Reduction in Water Usage for Ethanol Processing | 49 |
| 6.5 | Technology Changes and Reduction in Chemical Use | 49 |
| 6.1 | Recommendations Regarding Factors Influencing HPA Levels | 50 |
| 7. | References | 50 |

## Table of Figures

Figure 3-1. Corn Planting Decision Complexity .......... 10
Figure 3-2. Long-Term Acres Corn Planted .......... 13
Figure 3-3. Peaks in Corn Acres Planted in 2007 and 2012 .......... 15
Figure 3-4. Relationship Between Acres Planted and Futures Prices .......... 22
Figure 3-5. Relationship Between Corn Prices and the Implied Conventional Volume .......... 23

Figure 3-6. Relationship between Corn Futures Prices and Ethanol Production ....................................24
Figure 3-7. Relationship between Corn Futures Prices and Corn Stocks to Use Ratio .............................25
Figure 3-8. Relationship between Corn Acres Planted and the Implied Conventional Volume..................26
Figure 3-9. Relationship Between Corn Acres Planted and Ethanol Production ......................................27
Figure 3-10. Relationship Between Corn Prices and Crude Oil Prices ..................................................28
Figure 3-11. Relationship Between Corn Futures Prices and Soybean Futures Prices .............................31
Figure 5-1. Annual Nitrate and Nitrite Loading to the Gulf of Mexico 1980-2021..................................42
Figure 6-1. High Plains Aquifer (HPA) Water Level Changes from Pre-Development to 2017 in the Midwest of the US and Ethanol Refinery Locations based on their Capacity..........................................45
Figure 6-2. Comparison of Average Annual Precipitation to HPA Levels and Corn Production in Nebraska ..........................................................................................................................46

## Table of Tables

Table 2-1. Implied Conventional Volume in the RFS 2023 - 2025 ........................................................7
Table 3-1. Annual Spot Prices for Corn, Soybeans and Wheat ............................................................12
Table 3-2. Land Area Savings from DDGS ..........................................................................................18
Table 3-3. Projected Impact on Corn Prices Relative to the NO RFS Baseline .......................................19
Table 3-4. Corn Futures Prices Regression ..........................................................................................29
Table 3-5. Corn Production Regression ...............................................................................................32
Table 6-1. Technological and Methodological Improvements to Irrigation of Corn Crops........................47

## Acronyms and Abbreviations

| | |
|---|---|
| % | percent |
| CDL | Cropland Data Layer |
| CRP | Conservation Reserve Program |
| DDGS | distiller's dried grains with solubles |
| DRIA | Draft Regulatory Impact Analysis |
| EPA | Environmental Protection Agency |
| ERS | Economic Research Service |
| FAPRI | Food and Agricultural Policy Research Institute with Greenhouse Gases model |
| FASOM | Forest and Agricultural Sector Optimization international model |
| HPA | High Plains Aquifer |
| LUC | land use change |
| MTBE | methyl tertiary-butyl ether |
| NASS | National Agricultural Statistics Service |
| NGES | Net Gain Ecological Services |
| NWI | National Wetland Inventory |
| RFS | Renewable Fuel Standard |
| RIA | Regulatory Impact Analysis |
| RIN(s) | renewable identification number(s) |
| SRE(s) | small refinery exemption(s) |
| US | United States |
| USDA | United States Department of Agriculture |

# 1. Executive Summary

Ramboll and Net Gain Ecological Services have reviewed the Environmental Protection Agency's (EPA's) Proposed Renewable Fuel Standard 2023-2025 rule (the "Set Proposal" or "Proposed Rule") and the accompanying Draft Regulatory Impact Analysis (DRIA) along with many of the cited articles.[1] After careful review of the Set Proposal and the DRIA, and based on our own literature review and independent analysis, we find that there is no demonstrated causal link between the Renewable Fuel Standard (RFS), and land use change (LUC) or water quality. Furthermore, we conclude that the renewable fuel volumes suggested in the Proposed Rule for 2023-2025 are likely to have minimal or no effects on water quantity, quality or LUC. Our analysis focused on:

- The economic effect of the RFS on corn prices and acres planted in corn.
- The causal linkage between the RFS and LUC.
- Wetlands, ecosystems, habitat, and wildlife.
- Soil and water quality and water quantity.

## 1.1 Economic Analysis

Based on the economic research and regression analyses developed by Ramboll, we conclude that the RFS implied conventional renewable fuel volume (hereafter "the implied conventional volume")[2] has minimal to no effect on corn prices or acres of corn planted. The economic analysis we conducted for this report used EPA's DRIA as a foundation for evaluating the potential impact of the implied conventional volume on corn prices and acres of corn planted. We utilized 18 years of observational data in our models following fundamental economic theory. This evaluation was conducted and is reported in three main steps:

(1) Review of the Proposed Rule and DRIA.
(2) Review of relevant literature both criticizing and supporting the RFS.
(3) Development of a series of analytical models to determine which literature has the most accurate analysis and to determine whether the RFS is a driving factor influencing corn prices and acres of corn production.

For these purposes, EPA's DRIA reached the following significant economic conclusions:

- The net effect of the implied conventional volume on corn prices from the years 2023 through 2025 is estimated at $0.10/bushel, i.e., it is expected to be minimal. (DRIA, p. 409).
- Distiller's dried grains with solubles (DDGS) is a significant substitute for whole corn in the animal feed market. (DRIA, pp. 406–407).
- Year-ending corn stock-to-usage ratio (amount of corn production stored versus amount used) has a strong inverse correlation with corn futures prices and a dampening effect on prices in years when corn harvest is lean (DRIA, pp. 409–410).

The economic analysis literature review focuses on three primary papers:

[1] The recently released Draft Third Triennial Report to Congress External Review that is currently undergoing peer review was not reviewed as part of this analysis.
[2] See Section 2 for further explanation.

- Lark et al. (2022): Environmental outcomes of the US Renewable Fuel Standard.
- Austin et al. (2022): A review of domestic land use change attributable to U.S. biofuel policy.
- Taheripour et al. (2022a): Economic impacts of the U.S. Renewable Fuel Standard: An *ex-post* evaluation.

These three papers provide unique perspectives regarding the RFS program. Lark et al. (2022) takes an overall negative view of environmental and economic impacts of the RFS program. Austin et al. (2022) and Taheripour et al. (2022a) both contain information and analysis that highlight the deficiencies in Lark et al. (2015 and 2022, respectively).

Lark et al.'s (2022) results claim that for the years 2008 through 2016, the RFS program:

- Increased corn prices in the US by 30 percent (%).
- Increased the prices of other crops by 20%.
- Expanded US corn cultivation by 2.8 million hectares (equivalent to 6.9 million acres).

These findings would be reason for concern if valid and reliable; however, we demonstrate herein (Table 3-1 and Figure 3-2) that these results do not correspond with observed data from the referenced years (*e.g.*, corn prices fluctuated and were lower in 2016 than in 2008 and corn acres planted during the time frame of Lark et al.'s [2022] analysis were within historical levels). We conclude that Lark et al.'s (2022) analysis overestimates the impact of the RFS program on corn prices and corn acres planted as result of:

- Using a baseline that is too low (perhaps one third of what it should be).
- Focusing only on the US market and not accounting for the dampening effect of the global market corn prices and acres planted.
- Not accounting for the offsetting impact of DDGS as an animal feed replacement for corn.
- Not accounting for offsetting impact of increasing corn yield on acres planted.

Austin et al. (2022) reviewed and summarized 29 studies published since 2008 that attributed LUC in the United States (US) to the RFS program. In addition, they provided recommendations based on their analysis of the studies. We find that their most important recommendation is that to evaluate the effects of the RFS program, it is necessary to use an integrated model that captures global economy-wide interactions and simulates a detailed representation of the US land sector. Simply stated, a model that evaluates both global and domestic market interactions is needed.

We find that Taheripour et al. (2022a) provides the most credible work regarding the impact of the RFS program. We base this conclusion on the following attributes of their modeling approach:

- Uses an integrated model to account for global market interactions and US land sector.
- Includes an analysis of four different baselines across two different time periods.
- Accounts for increased corn yield, increased ethanol productivity, and the use of DDGS as a whole corn feed replacement.
- Uses observation data for the purpose of model calibration.

Below is a short list of conclusions reached by Taheripour et al. (2022a):

- Real crop prices have increased between 1.1 and 5.5% from 2004 to 2011 with only one-tenth of the price increases attributable to the RFS program.
- For 2011 to 2016, the long-run price impacts of biofuels were less than the period of 2004 to 2011.
- The impact of the RFS program on crop (i.e., corn, soybean, wheat) prices and acres planted is very small.

Regarding the DRIA, we find that the EPA uses an integrated model (DRIA Section 4.2.1.2) that includes international and domestic impacts and a baseline that assumes market production of ethanol without the RFS. The EPA's modeling approach is aligned with that of Taheripour et al. (2022a) and with the approach recommended by Austin et al. (2022). Therefore, EPA's results regarding the corn price impact of the RFS are more consistent with those found by Taheripour et al. (2022a) rather than those provided by Lark et al. (2022).

Ramboll performed its own economics analysis for the purpose of evaluating:

- The effect of the RFS and ethanol production on corn prices and acres of corn planted.
- Which research efforts best represent the potential effect of the RFS on corn prices and corn acreage planted.

Ramboll's analysis involves two primary analytical techniques: linear regression and the analysis of correlation coefficients. Linear regressions are commonly used in economics to establish empirical relationships between variables. Linear regressions can use either a single variable or multiple variables to identify the effect of one variable or a set of variables (i.e., explanatory variables) on the parameters of interest (i.e., dependent variables). Our analysis makes use of 18 years of observational data, i.e., 2005 to 2022. In presenting the result of our analysis we frequently use the term statistical dependency. This term means that a statistical relationship exists such that the independent values (i.e., potential explanatory parameter or X-value) can be used to approximate or explain the dependent value (i.e., value of interest or Y-value). Our analysis uses statistical results from linear regressions in conjunction with correlation to evaluating statistical dependency between the variables of interest and reaching reasonable conclusions regarding the potential degree of statistical dependency. Based on this analysis, we reached the following conclusions.

- The statistical dependency between corn prices and the implied conventional volume is either non-existent or very weak.
- The statistical dependency between corn prices and ethanol plant production is either non-existent or very weak.
- Multi-variate analysis indicates that the implied conventional volume and ethanol production have minimal to no effect on corn prices or corn acres planted.
- Corn futures prices are statically dependent on the corn ending stock-use-ratio and soybean futures prices.
- The number of corn acres planted is statistically dependent on corn futures prices and soybean futures prices; however, neither of these factors are statistically dependent on the RFS volumes.

Overall, our research concludes that the studies conducted by the EPA (2022b), and Taheripour et al. (2022a), are representative of the likely effects of the implied conventional volume and ethanol production on corn prices and corn acres planted whereas Lark (2022) is not.

## 1.2 Land Use Change

After our review of the EPA's analysis of potential LUC caused by the RFS, we find there is no evidence of a causal link between the RFS and LUC. We further find that the Proposed Rule is likely to result in minimal or no land conversion or significant adverse effects to wetlands, ecosystems, wildlife habitat, or water quality. Our analysis reviews the cited literature in the Proposed Rule and DRIA in addition to other pertinent documents. LUC is referred to in several different sections in Chapter 4 of the DRIA. In these sections, we find that the EPA cites many articles that erroneously purport to establish a causal connection between the RFS and LUC without clearly explaining the shortcomings of the erroneous literature, or consistently citing the literature that finds errors in the methodology. We recommend that in the final Regulatory Impact Analysis (RIA), the EPA clearly document the shortcomings of studies purporting to show a causal link between the RFS and LUC and cite literature critical of those studies. Specifically, we have the following recommendations for how EPA can improve its analysis:

- In the Air Quality section (DRIA section 4.1) and the Conversion of Wetlands, Ecosystems, and Wildlife Habitat Section (DRIA section 4.3), we recommend that the EPA explicitly acknowledge the shortcomings in the use of the Cropland Data Layer (CDL) for analysis of LUC to and from agriculture. The CDL has been documented to poorly differentiate between native grassland, pasture, fallow land, and crops which results in an overestimation of LUC (Copenhaver 2022; Dunn et al. 2017; Pritsolas and Pearson 2019; Shrestha et al. 2019; and Taheripour et al. 2022b). The CDL also has a resolution of 30 to 56 meters, which is too coarse for accurate measurement of LUC (Copenhaver 2022). Unfortunately, several heavily cited papers in the DRIA rely on the CDL to causally link the RFS program to LUC. Papers which depend upon the CDL for their analysis include Lark et al. (2015), Lark et al. (2021), Lark et al. (2022), Wright et al. (2017), and Johnston (2013). When these papers are cited, EPA should acknowledge that they rely on the CDL and refer to an explicit description of the shortcomings of using the CDL to quantify LUC.
- Several cited papers causally attribute LUC to the RFS program without having conducted a quantifiable causal analysis. For example, some authors attributed causality while admitting that other factors were not considered (Wright et al. 2017). We recommend that when the EPA cites these documents, it explicitly acknowledges that a causal analysis was not carried out. The final RIA should include citations for several recent articles that the DRIA does not cite: Copenhaver (2022), Dunn et al. (2017), Shrestha et al. (2019), Pritsolas and Pearson (2019), and Taheripour et al. (2022b). The EPA should acknowledge that these papers analyzed the work of Lark et al. (2015), Lark et al. (2022), and Wright et al. (2017), and clarified the weaknesses in their analyses.
- Finally, some of the cited articles in the DRIA imply, without adequate support or analysis, that a farmer's decision on crop type and where to plant is strongly determined by the RFS (Johnston 2013; Wright et al. 2017). The EPA should clarify that an individual farmer's decision is complex and may take into account many factors including: weather, soil health, market prices, land availability, contracts, prices for other crops, agricultural pests, and other factors.

## 1.3 Soil and Water Quality

In addition to LUC, the EPA discusses the effects of additional farming pressure on soil and water quality in Section 4.4 of the DRIA. However, because the lack of a *causal* relationship between the RFS and soil and water impacts is not clearly stated in Section 4.4, this this section may wrongly imply that there is such a causal relationship. The soil and water quality section states that "impacts to soil and water quality depend upon the feedstock grown and land use – i.e., the type of land used for growing the biofuel feedstock and the management implemented on that land" (DRIA, p. 254). The section then goes on to detail the negative effects of extensification to soil and water quality. But in the LUC section of the DRIA (DRIA section 4.3) the EPA stated it could not quantify any relationship between the RFS program and LUC[3]. In the beginning of the Soil and Water Quality section (DRIA section 4.4), the EPA explains that additional farming pressure can be caused by either intensification or extensification and can cause further use of pesticides and fertilizers which may lower soil and water quality. The EPA also states that extensification causes more harm than intensification[4], further strengthening the implication that soil and water quality are negatively affected by extensification caused by the RFS. Ramboll and Net Gain Ecological Services (NGES) recommend the following specific changes for the final RIA:

- Clearly state that the EPA has not found a causal link between the RFS program and LUC or extensification in the beginning of the section to alleviate misunderstandings.
- Remove the text calculation (DRIA, p. 255) of a theoretical increase in nitrogen applied to farm fields nationwide due to corn extensification for two reasons: 1) the EPA reported in Section 4.3 of the DRIA that there was has been no quantifiable causal link shown between the RFS and LUC (extensification)[5]; 2) the calculation itself is flawed because the assumption regarding acres of extensification for corn is based on the work of Lark et al. (2015), which is unreliable due to its reliance on CDL data.
- Clearly state that there is no known causal link between the RFS and negative effects to soil health or water quality.
- When mentioning that nutrient loading causes hypoxic zones (DRIA, p. 260), include necessary context such as the US Geological Survey (2021), which shows that nitrogen loading to the Gulf of Mexico remained fairly constant from the early 1990s through about 2008 and then actually began a decreasing trend. Thus, it is unlikely the hypoxic zone is causally tied to the RFS.

## 1.4 Water Quantity and Availability

We agree that additional farming pressure could lead to more irrigation in water stressed regions without adequate natural rainfall; however, the EPA has not identified any causal connection between the RFS and additional farming pressure. Indeed, we agree with EPA's statement that, "[t]o our knowledge, 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" (DRIA, p. 273). The EPA finds no quantitative causal link between the RFS and negative environmental effects, which in this case is water quantity. The EPA should therefore make it

[3] DRIA Section 4.3, p. 240 – "However, at this time we cannot quantify the amount of land with increased intensity of cultivation nor confidently estimate the portion of crop land expansion that is due to the market for biofuels."

[4] DRIA Section 4.4.2.1, p. 254 – "For a given acre of cropland, planting corn or soybeans onto grasslands (extensification) can be expected to have greater negative effects on soil and water quality relative to the conversion of other existing cropland, such as wheat, to corn or soybeans (intensification)."

clear that section 4.5 of the DRIA is not intended to imply that there is such a causal link. We recommend the following changes for the final RIA:

- Clearly elucidate that there is no published evidence of a causal link between agriculture for biofuel and reductions in surface water or groundwater supplies.
- Remove the citations to Lark et al. (2015) and Wright et al. (2017) in this section as evidence of LUC which could increase irrigation. As explained above, these articles are flawed in their calculation of LUC because of their dependence on the CDL.
- Acknowledge that most of the corn produced for biofuel in Nebraska is grown in regions of the state that primarily use precipitation for crop growth.
- Add information on other factors besides agriculture that affect aquifer levels, such as precipitation patterns and associated recharge, drought years, and technology that improves the efficiency of agricultural and ethanol production.

We encourage the EPA to update its analysis so that the final RIA addresses the above recommendations. Even in its draft form, EPA's analysis firmly supports that the volumes proposed for 2023 through 2025 are unlikely to result in adverse environmental impacts.

## 2. Introduction

EPA (2022a) proposes volume standards for 2023 through 2025 for cellulosic biofuel, biomass-based diesel advanced biofuel, and total renewable fuel. The focus of Ramboll's analysis is on the economic impact of the conventional renewable fuel volume established by the RFS with respect to potential effects on LUC, habitats, wildlife, and water quality and quantity. Conventional renewable fuel is that portion of the total renewable fuel that meets a 20% greenhouse gas reduction standard and does not qualify as advanced, cellulosic, or biomass-based diesel biofuel. For purposes of this report, conventional renewable fuel, for which there is an implied volume requirement rather than an explicit requirement, refers to ethanol made from corn starch.

Table 2-1 below is an abbreviated version of Table I.A.1-1 from EPA (2022a). The table summarizes the implied conventional renewable fuel volume requirement, which we refer to in this report as the implied conventional volume, for the years 2023 to 2025. All volumes are in billions of gallons per year. Note that the implied conventional volume is obtained by subtracting the advanced biofuel volume from the total renewable fuel volume. The implied conventional volume is 15.00 billion gallons per year for 2023 and 15.25 billion gallons per year for 2024 and 2025. It should be noted that the projected amount of the implied conventional volume to be made up of corn ethanol for the years 2023, 2024 and 2025 are 14.455, 14.505 and 14.534 billion gallons respectively (EPA 2022a Table III.C.3-1). However, for the purpose of this analysis Ramboll made the simplifying and conservative assumption that the implied conventional volumes listed in Table 2-1 would be made up entirely of corn ethanol.

**Table 2-1. Implied Conventional Volume in the RFS 2023 - 2025**

| | 2023 | 2024 | 2025 |
|---|---|---|---|
| Total Renewable Fuel | 20.82 | 21.87 | 22.68 |
| Advanced Biofuel | 5.82 | 6.62 | 7.43 |
| Implied Conventional Volume | 15.00 | 15.25 | 15.25 |

Source: EPA 2022a

The focus of Ramboll's analysis is on the impact of the implied conventional volume on corn prices, the number of acres of corn planted annually, and other environmental effects. Although the Set Proposal pertains to the years 2023 to 2025, our analysis also considers the impact for the years 2005 through 2022. This is because understanding past impacts is useful for evaluating the quality of forecasted impacts provided by the DRIA. (i.e., EPA 2022b). In addition, understanding past impacts is required to address assertions by some researchers that the RFS program has led to significant increases in corn prices and LUC by the conversion of formerly non-tilled land, or land used for other crops, into land used for corn crops.

In this report, we review and evaluate EPA's Set Proposal and DRIA, including selected literature the agency newly references, and we continue to find that there is no evidence the RFS program causes the above listed adverse environmental impacts. We agree with EPA's finding that there is no evidence the Proposed Rule causally links to land conversion or adverse impacts to wetlands, ecosystems, wildlife habitat, water availability or water quality. We encourage the EPA to update its analysis in the final RIA to address these findings and revise its potentially misleading discussion of environmental impacts of the program where noted.

## 3. Economic Analysis

This section describes the economic analysis performed by Ramboll to evaluate the impact of the Proposed Rule with respect to corn prices and potential implications for LUC. The DRIA contains a significant amount of information indicating that since the inception of the program, the RFS has had minimal impacts on corn prices and corn acres planted in the past and will likely have minimal impacts in the future. The DRIA contains the following information that Ramboll concludes are reasonable based on our literature review and our own economic analysis, though EPA may overstate the (minimal) impact of the proposed volumes on corn price:

- Trends from 1995 through 2021 indicate that corn production grew steadily at a 25-year average rate of around 2%, or 250 million bushels per year, with no apparent correlation to ethanol production volumes.
- The net effect of the RFS on corn prices throughout the years 2023 through 2025 is 3%, which is equivalent to $0.10/bushel (depicted in Table 3-3). Ramboll's economic analysis did not involve forecasting the impact of the implied conventional volume on corn price. However, our modeling indicates that **the statistical dependency between the implied conventional volume and corn prices is non-existent to very weak**. Therefore, it possible that the impact of the implied conventional volume on corn prices would be much less than $0.10/bushel.

- DDGS, a byproduct of ethanol production, represents a significant factor in the shift of animal feed away from whole corn (i.e., DDGS is a significant substitute for whole corn in the animal feed market).
- Year-ending corn stock-to-usage ratio (amount of corn production stored versus amount used) has a strong inverse correlation with corn futures prices and a dampening effect on prices in years when corn harvest is lean.
- Corn futures prices are a critical factor in farmer's planting decisions.
- The RFS has little to no impact on corn futures prices.

Our economic analysis involved the following four activities:

1. Review of the Set Proposal (EPA 2022a) and the associated DRIA (EPA 2022b).
2. Literature review of research focusing on the economic impacts of the RFS program since inception, particularly in relation to corn prices and annual corn acreage planted.
3. Review of analytical methods used by researchers to evaluate the impact of the RFS program on corn prices and corn acreage planted.
4. Development of our own analytical models for purposes of confirming and/or refuting information in the DRIA and the work performed by other researchers.

Since estimates of the impacts of the RFS (whether developed by the EPA or other researchers) are based on economic modeling, Section 3.1 is included for purposes of describing the complexities associated with modeling the system of interactions that result in corn prices and number of corn acres planted each year. Section 3.2 summarizes our literature review including the assertions of researchers critical and supportive of the RFS program. Section 3.3 presents the results of Ramboll's modeling efforts that evaluate, at a high level, the modeling efforts by EPA and other researchers to estimate the impact of the RFS on corn prices and acres planted. Section 3.4 summarizes the economic analysis results and conclusions.

## 3.1 Complexities in Modeling the Effect of the RFS on Corn Prices and Acres Planted

As previously stated, the EPA has a statutory obligation to perform an analysis of various environmental and economic impacts of proposed RFS volumes. Economic modeling is useful for such an analysis. The EPA's modeling is forward looking, meaning that it focuses on estimating the impact of the RFS in years 2023, 2024, and 2025. To perform such a forward analysis, the EPA develops two models; the first assumes that the proposed RFS is in place and the second assumes that the RFS is not in place. This second model is a baseline model.

In the future, after the proposed RFS volumes are implemented, it will be possible to collect observational data regarding corn prices and acres planted for the years 2023 through 2025. However, to evaluate the impact of the RFS program, additional modeling efforts will be required. This is because it is not possible to collect observational data for a baseline that assumes no RFS program, when in fact the RFS has been implemented. Therefore, the EPA, or any other research group interested in studying the impact of the RFS program, must develop a baseline model for purposes of comparison. As we demonstrate in Section 3.3, the baseline model and its associated assumptions are crucial to such analysis.

The EPA's modeling efforts go beyond estimating the impacts of the RFS program on corn prices and acres planted in corn. However, many of the other impacts such as the effect on habitat, endangered species, and undeveloped land directly or indirectly relate to changes in the number of acres planted in corn. Therefore, models that can reasonably estimate acres planted in corn, under the assumptions of RFS or no RFS (baseline), are fundamental to evaluating all other impacts.

A fundamental economic principle is that an increase in demand for a particular product will lead to an increase in the price of that product. This is because as demand increases, producers will be able to charge more for the product without experiencing a decrease in the number of products sold (in economic terms, such increased demand is known as an upward shift in the demand curve). Another fundamental principle is that as the price increases, more suppliers will enter the market to take advantage of the higher prices and the opportunity to achieve higher profits. Eventually, as more product is supplied, demand will be met, and producers will have to lower the price to move excess product (the lowering of prices because of increased supply in economic terms is referred to as a downward shift in the supply curve).

A general concern of those critical of the RFS program is that it induces increased demand for ethanol to meet the implied conventional volume. These individuals further assume, based on basic economic principles, that the induced demand for ethanol will increase demand for corn which will in turn increase corn prices. Finally, in this chain of impacts, they assume that farmers will plant more acres of corn to sell at these higher prices. There is concern that available tillable land for corn planting will be exhausted and landowners will begin converting other land previously not used for corn agriculture (e.g., wetlands or grasslands) or they will divert land used for other crops to corn production. The concern regarding the latter choice is that the prices of other crops will go up since their supply in the market would be reduced. Lark et al. (2022) has engaged in significant analysis and modeling which they believe validates this chain of impacts. However, as discussed in the Economic Literature Review section, Ramboll disagrees with Lark et al.'s (2022) results.

Although critics of the RFS program correctly rely on fundamental economic principles, they make errors including assuming a closed system and oversimplifying the planting decision. Assuming a closed system is incorrect because the price of corn within the US is only partially based on economic activities within the US. In reality, there is a great deal of global trade in corn and ethanol. The price of corn within the US is strongly affected by global supply and demand as well as policies in other countries and complex trade agreements. Simplistic concepts of supply and demand do not account for all the complexities associated with global markets. Furthermore, very complex economic modeling is needed to simulate all the interrelated realities of the corn planting decisions made by individual farmers. Figure 3-1 provides a conceptual model of many the factors that farmers may consider when deciding how much of their land to plant in corn and whether to invest in methods to increase corn yield (intensification).

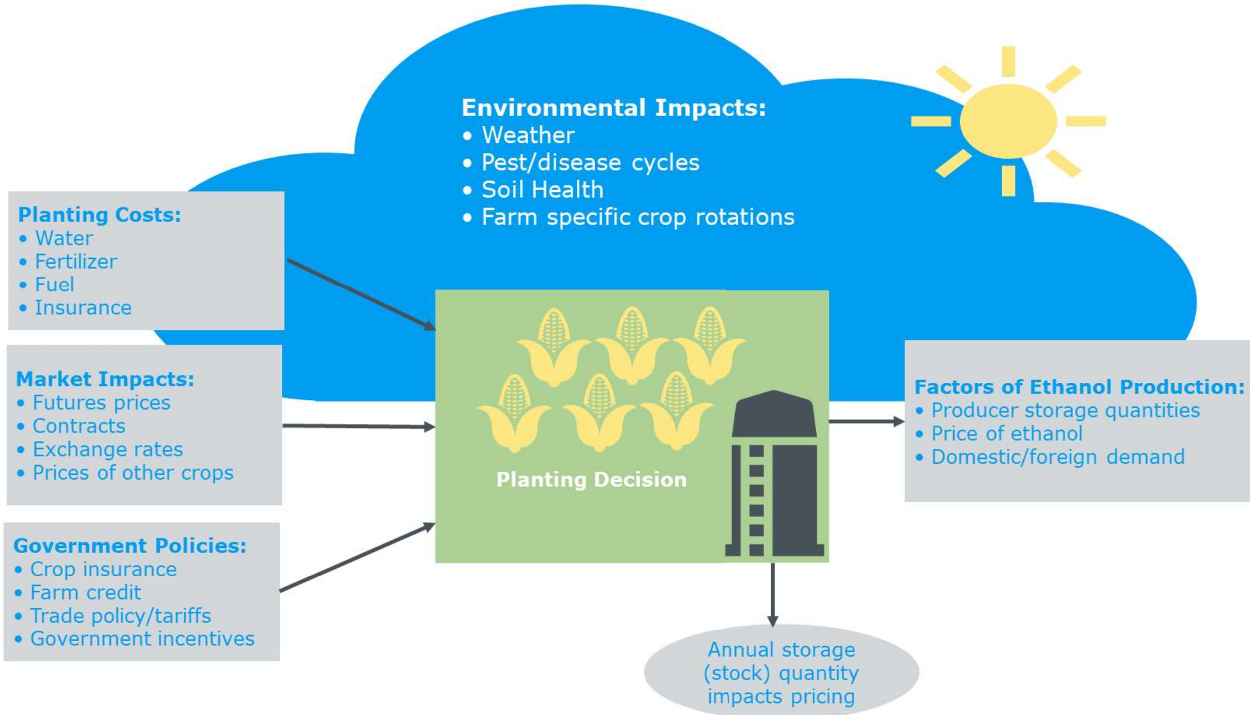



**Figure 3-1. Corn Planting Decision Complexity**

The various inputs known to play a crucial role in farmer planting decisions include weather, soil health, market prices, land availability, contracts, prices for other crops, and agricultural pests, among others.

It is likely that large corporate farming operations adjust their planting based on all the factors presented in Figure 3-1. However, according to the US Department of Agriculture (USDA), approximately 89% of all US farms are small family farms, having a gross cash farm income of less than $350,000, and these farms make up approximately 53% of corn production (USDA Economic Research Service [ERS] 2022). With small family farms in the US producing most of the corn, farmers may not be able to plant the crop that simply produces the best market prices. Instead, they may need to honor crop rotations, the demands of other aspects of their farm operations (land needed for grazing cattle or sheep), and other factors important to farmers at this scale.

With so many variables entering into the corn planting decision at the local level, isolating and modeling the effects of a single factor such as the renewable fuel volume is extremely difficult. This is especially true when one considers that corn ethanol was being produced prior to the RFS program and that ethanol production would continue without the RFS program. Ethanol production would continue because ethanol is used in many different markets including fuel, pharmaceuticals, cosmetics, and beverages. In addition, ethanol would continue to be added to gasoline as an oxygenate due to the ban on methyl tertiary-butyl ether (MTBE[5]) implemented in 2006. The fact that ethanol production occurs regardless of the RFS program further complicates isolating the effect of a specific policy driven factor.

Ramboll analyzes ethanol production and the implied conventional volume for the years 2005 through 2022. The year 2005 is chosen as the starting point since it represents the year before the RFS program was implemented. In 2005, a total of four billion gallons of ethanol was produced without the incentive of the RFS program. This analysis further indicates that over the 16-year period, actual ethanol production exceeded the implied conventional volume in all but four years, i.e., 2012, 2013, 2014 and 2020 (it should be noted however that 2012 was an extreme drought year and the COVID-19 pandemic was occurring in 2020). In addition, actual ethanol production exceeded the implied conventional volume by an average of 0.73 billion gallons throughout the period of 2006 through 2022. This indicates that the rate of ethanol production is likely determined more by market demand than by the RFS. Furthermore, it demonstrates that it is very difficult to isolate the impact of the RFS from general market demand.

### 3.2 Economic Literature Review

This section incorporates a review and summary of recent relevant literature regarding the potential impact of the RFS program on the corn industry.

We review the following key papers:

- Lark et al. (2022): Environmental outcomes of the US Renewable Fuel Standard.
- Austin et al. (2022): A review of domestic land use change attributable to U.S. biofuel policy.
- Taheripour et al. (2022a): Economic Impacts of the U.S. Renewable Fuel Standard: An *Ex-Post* Evaluation.
- EPA (2022b): Draft Regulatory Impact Analysis: RFS Standards for 2023-2025 and Other Changes.
- Taheripour et al. (2022b): Comments on "Environmental Outcomes of the U.S. Renewable Fuel Standard."
- Taheripour et al. (2022c): Response to Comments from Lark et al. Regarding Taheripour et al. March 2022 Comments on Lark et al. Original PNAS Paper.
- Carter et al. (2017): Commodity storage and the market effects of biofuel policies.
- Carter et al. (2011): Commodity booms and busts.

Much of the information in this section pertains to the first three papers i.e., Lark et al. (2022), Austin et al. (2022), and Taheripour et al. (2022a), along with the DRIA (EPA 2022b). We use the remaining documents to a lesser degree, primarily to address issues or call attention to data that either confirms or refutes information in the first three papers and the DRIA.

We give special attention to the first three papers in this list because they provide three unique perspectives regarding the RFS program. Lark et al. (2022) took an overall negative view of economic and environmental impacts of the RFS program. Austin et al. (2022) reviewed and summarized 29 studies published since 2008 that attributed US LUC to the RFS program. In addition, Austin et al. (2022)

[5] MTBE was used in gasoline starting in the mid-1980s to increase efficiency and reduce pollution. However, MTBE was found in some water sources and in blood in humans and was then banned in several states (Centers for Disease Control and Prevention 2017). Ethanol provides oxygenation of gasoline similar to MTBE and has been used as a replacement (Kanaskie 2000).

provided recommendations based on their analysis of the various studies. Taheripour et al. (2022a) refuted many of the statements contained within Lark et al. (2022).

### 3.2.1 Lark et al. (2022)

The Lark et al. (2022) paper focused on presumed negative externalities associated with the production of corn-based ethanol in the US, namely, reducing land used for conservation, water quality, and failing to meet the reduced greenhouse gas emissions reduction goals of the program (Lark et al. 2022). From a strictly economic perspective, the findings of concern in the Lark et al. (2022) paper are that for the years 2008 through 2016 the RFS:

- Increased corn prices in the US by 30%.
- Increased the prices of other crops by 20%.
- Expanded US corn cultivation by 2.8 million hectares (equivalent to 6.9 million acres).

These findings would be reason for concern if they were credible; however, they do not correspond with observed data from the referenced years. Table 3-1 below presents the average annual spot price data for corn, soybean and wheat as obtained from the USDA. A review of this data indicates the prices for all three crops varied widely throughout this time frame and the spot price for each crop was lower in 2016 than in 2008.

**Table 3-1. Annual Spot Prices for Corn, Soybeans and Wheat**

| Year | Average Annual Corn Spot Prices | Average Annual Soybean Spot Prices | Average Annual Wheat Spot Prices |
|---|---|---|---|
| 2008 | $5.30 | $12.32 | $7.99 |
| 2009 | $3.75 | $10.20 | $5.34 |
| 2010 | $4.31 | $10.49 | $5.87 |
| 2011 | $6.80 | $13.19 | $7.14 |
| 2012 | $6.92 | $14.62 | $7.54 |
| 2013 | $5.69 | $13.86 | $6.86 |
| 2014 | $4.16 | $12.29 | $5.89 |
| 2015 | $3.78 | $9.42 | $5.08 |
| 2016 | $3.60 | $9.88 | $4.39 |

Given that the spot price for corn in 2016 was below the price in 2008, one could argue that the lower prices represent the long-term result of increased corn acres planted; perhaps as much as 6.9 million acres as reported Lark et al. (2022). However, USDA data from 1926 to 2022 indicate that there has not been a significant increase in corn production acres, but rather a decrease in total acres of corn planted across the US (see Figure 3-2). The data show peak acreage was planted in 1932 at 113 million acres (USDA National Agricultural Statistics Service [NASS] 2023a).

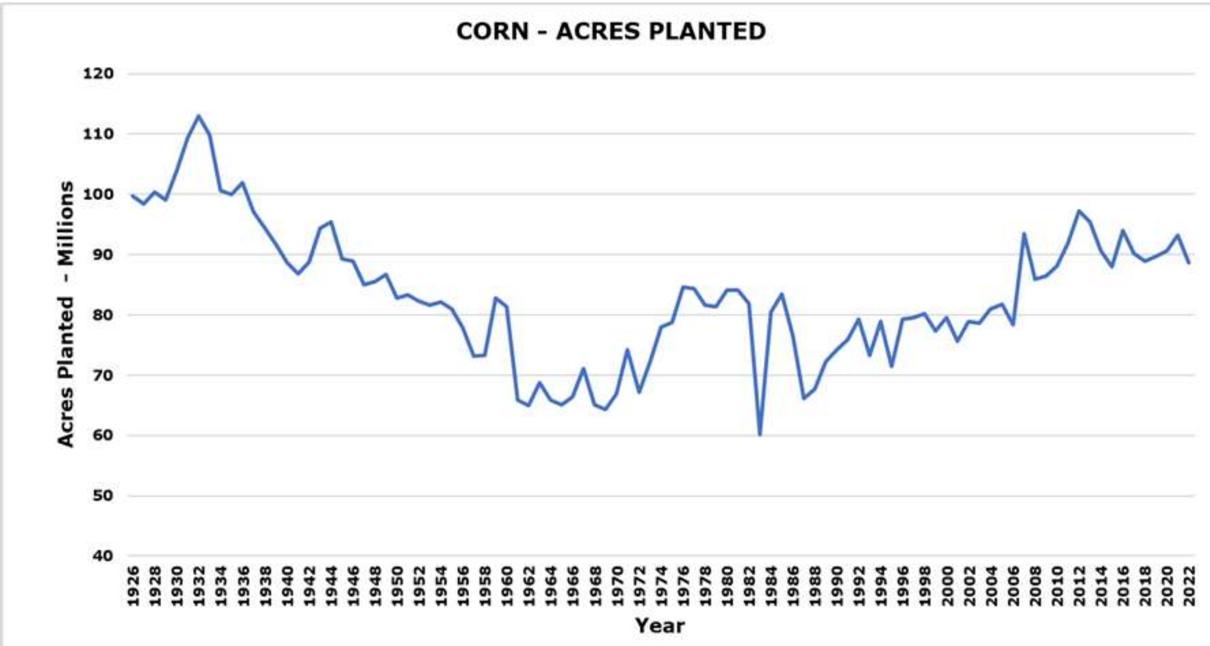



**Figure 3-2. Long-Term Acres Corn Planted**
Data Source: Corn Acres Planted – USDA NASS 2023a

Given the information in Table 3-1 and Figure 3-2, many would find it difficult to understand how Lark et al. (2022) could make claims that corn prices have increased by 30% and corn acres cultivated have expanded by 6.9 million acres. The answer is likely found in the choice of baseline and modeling methodology in Lark et al. (2022).

Although the baseline chosen by the Lark et al. (2022) paper included only the ethanol needed to meet the requirements under the 1990 Clean Air Act for reformulated gasoline across the period, it is not clear what baseline volume of ethanol production is assumed in their model. Additional online research to assess the volume of ethanol production assumed by the Clean Air Act did not readily produce this information. However, the baseline volume of ethanol production that is assumed in their model appears to be the volume needed to replace MTBE as a fuel additive. According to published transcripts of a 2003 hearing before the US Senate Subcommittee on Clean Air, Climate Change and Nuclear Safety "between 3.5 and 4.5 billion would be needed to replace MTBE." (US Government Printing Office 2004). We believe that Lark et al. (2022) used a volume within this range throughout the time frame of their analysis (2008 to 2016). In addition, it is likely that they used a volume of 4.0 billion gallons, since this was the amount produced in 2005 without the incentive of the RFS program. As previously discussed, the market demand for ethanol on average has been above the implied conventional volume for the period that the program has been in existence (2006 through 2022) by approximately 0.73 billion gallons. The average implied conventional volume for the period analyzed by Lark et al. (2022) is 12.4 billion gallons. Although it is very difficult to determine the annual baseline volume of ethanol production (i.e., the volume of ethanol that would have been produced without the implied conventional volumes) it is likely much higher than the value used by Lark et al. (2022), perhaps as much as three times higher. This is because it appears that Lark et al. (2022) may have used a baseline of 4.0 billion gallons of ethanol and that market demand for ethanol generally has been above the implied convention volume. Therefore, the market demand is likely very close to the average implied conventional volume throughout the period of Lark et al.'s (2022) analysis, i.e., approximately 12 billion gallons.

The methodology in Lark et al. (2022) involved the creation of two distinct models. The first model focused on estimating the effects of the RFS on crop prices. According to Lark et al. (2022), their approach for modeling impacts of the RFS on crop prices closely followed methods used by Carter et al. (2017) but incorporated the RFS program as a persistent shock to the agricultural markets rather than a transitory shock whose price impacts are different (Lark et al. 2022). In addition, Lark et al. (2022) noted that they extended the work of Carter et al. (2017) to include the impact of the RFS program on soybean and wheat prices. Lastly, Lark et al. (2022) explained that their pricing model accounted for the effect of year end storage of crops (i.e., corn, soybeans, wheat), which as they noted, is a staple of literature on the prices of storable commodities.

The second model included in Lark et al. (2022) involved a regression model focused on estimating the probability of crop rotations. Specifically, Lark et al. (2022) assessed the impact of the RFS program on cropland based on the probability of cropland expansion and abandonment at the field level.

Lark et al. (2022) provided additional details regarding their methodology in the supplementary information associated with their report, although working through the various details of this methodology is beyond the scope of this analysis. However, there are two important points regarding this approach that are worth noting. The first is that Lark et al. (2022) was focused, in terms of spatial extent, exclusively on the market within the contiguous US as a closed system. However, the work by Austin et al. (2022) highlighted that studies which only considered domestic impacts reported higher level impacts of the RFS than those that considered global markets, because corn and ethanol are globally traded commodities. The global lens is more appropriate because the global market can dampen the impact of increased demand and/or supply of either commodity.

It is also important to note that the probability model developed by Lark et al. (2022) operated at a field level degree of spatial resolution. Specifically, the identified fields were based on the USDA's common land use boundary. From the standpoint of economic modeling, this is an extremely granular model. In economics, high granularity indicates that the model is attempting to predict the actions of fewer individuals. For example, it is extremely difficult to predict whether one individual will buy a new car in the next year based on population level data, but we can predict how many individuals out of 1,000 will buy a new car in the next year with much more confidence. It is our experience that with any economic modeling effort, increased levels of granularity introduce increased levels of uncertainty due to difficulties obtaining data and structuring simulation models representative of actions at such a high degree of resolution. In essence, the modeling approach of Lark et al. (2022) was aimed at estimating the likely decisions of individual landowners, which can introduce too much variability into the model of a larger market.

Lark et al. (2022) called attention to two peaks in the observed acres planted in corn that were significantly above their assumed baseline, which they attributed to the RFS program. These peaks occurred in 2007 and 2012 and are presented in Figure 3-3.

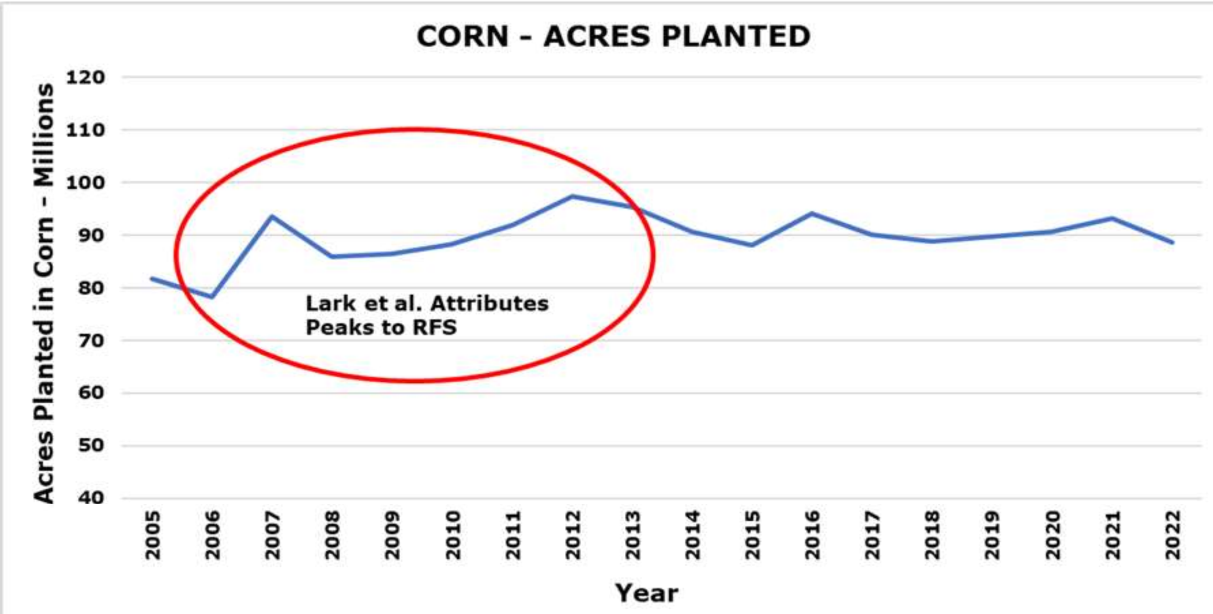



**Figure 3-3. Peaks in Corn Acres Planted in 2007 and 2012**
Data Source: Corn Acres Planted – USDA NASS 2023a

While Lark et al. (2022) attributed the increases in corn acres planted in 2007 and 2012 solely to the RFS program, other researchers, i.e., Taheripour et al. (2022a), credited the temporary increases to other factors including:

- Ban of use of MTBE in 2006 as a gasoline additive.
- Tax exemption for ethanol of $0.40/gallon through 2011 established by National Energy Conservation Policy Act.
- State incentives for biofuel production.

Carter et al. (2011) offered two additional explanations for the commodity price boom of 2008: rising global demand and weak US federal policy.

In summary, we believe the analysis presented in Lark et al. (2022) overestimates the impact of the RFS program on corn prices and corn acres planted primarily by using a baseline that is too low (perhaps one third of what it should be) by assuming that the implied conventional volume is the only driver for ethanol production. In addition, their approach focused only on the US market which does not account for the dampening effect of the global market on corn prices and acres planted. Furthermore, the model is very granular, from an economics point of view, which in most cases introduces much uncertainty. Lastly, as we shall see in the comments provided by Taheripour et al. (2022a), Lark et al. (2022) did not account for the impact of DDGS as an animal feed replacement for corn. Nor did Lark et al. (2022) account for the effect of increased corn yield.

### 3.2.2 Austin et al. (2022)

Austin et al. (2022) reviewed a total of 29 studies published since 2008 which attributed domestic LUC to the RFS program. These studies resulted in a wide range of LUC estimates depending on factors such as:

- Type of economic models utilized (simulation based or empirical methods).
- Key attributes or parameters included in the studies.
- Baseline scenario chosen.
- Land use effect (i.e., change in corn crop, change in Conservation Reserve Program [CRP] acreage: changes among cropland, cropland pasture, forested pasture, timberland, developed land, etc.).
- Spatial extent (i.e., global, contiguous US, US region, group of states, particular states).
- Spatial resolution (region of the US, US counties, crop reporting districts, defined grids cells [e.g., 10 by 10 kilometers, 30 by 30 meters, 3.5 by 3.5 miles]).

Austin et. al. (2022) reported that the economic simulation models provided a range of 0.01 to 2.24 million acres of net cropland expansion per billion-gallon increase in biofuels. This is a wide range, spanning two orders of magnitude. Such a wide range demonstrates the difficulties in creating representative models when so many variables are involved.

Furthermore, Austin et al. (2022) noted that in general, international models that capture global responses have a smaller range of variability in corn acres planted. Simply stated, they reasoned that the global market worked to dampen the effect of increased demands in commodities such as corn and ethanol in the US market (i.e., these demands can be met by the global supply).

In addition to differences in geographic scope and resolution, Austin et al. (2022) highlighted that the time periods over which the studies evaluated LUC were highly variable. The time frames ranged from 3 to 30 years. Such a wide range of variability makes it difficult to make substantive claims regarding a general or universal conclusion common among all studies.

Based on a review of the various papers, Austin et al. (2022) made an important point that an ideal simulation modeling study would be global in scope, account for trade dynamics, include international market interactions, and would represent all relevant market interactions together with agricultural, forestry, land transportation, and energy markets (Austin et al. 2022). Moreover, Austin et al. (2022) added that one approach to reconciling these competing goals would be to develop an integrated model that leveraged the benefits of computable general equilibrium modeling to capture global economy-wide interactions and partial equilibrium models that supply a detailed representation of the US land sector.

In addition to creating the combined model as suggested by Austin et al. (2022), based on our analysis of the literature, Ramboll would add that it is important to select a proper time range for the evaluation, establish a proper baseline, account for increased corn yield and increased ethanol productivity, and make use of observed data for model calibration.

### 3.2.3 Taheripour et al. (2022a)

"Economic Impacts of the U.S. Renewable Fuel Standard: An Ex-Post Evaluation" by Taheripour et al. (2022a) provides the most representative work in our review regarding the impact of the RFS program. We base this conclusion on the following attributes of the work in Taheripour et al. (2022a):

- Use of general equilibrium modeling to account for the global market interactions and partial equilibrium modeling to account for the US land sector.
- Spatial resolution based on US agro-ecological zones (10 in the US).
- Evaluation of a 12-year time frame, 2004 through 2016.
- Inclusion of the analysis of four different baselines across two different time periods, i.e., 2004 to 2011 and 2011 to 2016. The time separation was done because, during the period of 2004 through 2016, crop and food prices followed an upward trend until 2012 and then tracked downward. This trend is seen in the US and globally as well.
- Accounts for increased corn yield, increased ethanol productivity, and the introduction of DDGS as a whole corn feed replacement.
- Use of observed data for the purpose of model calibration.

Below is a short list of conclusions reached by Taheripour et al. (2022a) based on their modeling approach.

1. The bulk of ethanol production prior to 2012 was driven by what was happening in the national and global markets for energy and agricultural commodities.
2. Regardless of the drivers, real crop prices have increased between 1.1 and 5.5% from 2004 to 2011 with only one-tenth of the price increases attributable to the RFS program.
3. For 2011 to 2016, the long-run price impacts of biofuels were less than the period of 2004 to 2011.
4. If there were no RFS program, farmers in the US would produce less corn by 1.2%.
5. When removing the RFS volumes for both ethanol and biodiesel outputs for corn, soybeans, rapeseed, and other oilseeds drop by 1.4, 1.6, 12.4, and 4.3%, respectively.
6. Ignoring the contributions of non-RFS factors, the impact of the RFS on crop prices and acres planted is very small.

The results from Taheripour et al. (2022a) provide considerable evidence that the RFS program has had little impact on both the price of corn and corn acres planted. These results appear to be consistent with observed changes in corn prices shown in Table 3-1 and the long-term acres of corn planted as shown in Figure 3-2; more so than the results produced by Lark et al. (2022).

Taheripour et al. (2022b) produced a second paper for the purpose of providing comments to Lark et al. (2022). One of the comments provided by Taheripour et al. (2022b) was that Lark et al. (2022) reached LUC conclusions without careful consideration of corn yield increases over time and DDGS offsets. As a demonstration of these impacts, Taheripour et al. (2022b) provided an analysis showing an overall net **reduction** of 4.262 million acres of land needed to meet the volume for the RFS in 2008. A summary of their analysis is presented in Table 3-2 below.

**Table 3-2. Land Area Savings from DDGS**

| Base Year | Acres |
|---|---|
| 1. Gross acres needed for increased ethanol volume | 10,862,266 |
| 2. Land area spared due to DDGS production | -5,539,158 |
| 3. Land area spared from corn yield increases on 2008 corn acres (no ethanol production) | -9,585,000 |
| 4. Net land area (1+2+3) after considering DDG with ethanol production and corn yield increases | -4,261,892 |

Source: Taheripour et al. 2022b.

Assuming that this analysis is correct, it is likely that similar, if not larger, net reductions in land needed for corn production would be present throughout the time frame of the RFS program.

### 3.2.4 EPA DRIA (2022b)

The significant differences regarding the impacts of the RFS program on corn prices and corn production reported by Lark et al. (2022) and Taheripour et al. (2022a; 2022b) demonstrate the need to understand the modeling approach EPA uses before comparisons can be made between the results reported by these researchers and those EPA reports in the DRIA (EPA 2022b).

When the EPA was drafting the 2010 RFS rule, the agency developed an integrated model that utilized both the Forest and Agricultural Sector Optimization Model with Greenhouse Gases model ("FASOM model") and the Food and Agricultural Policy Research Institute international model,("FAPRI model") developed at the Center for Agriculture and Rural Development at Iowa State University, as well as data from many other sources (EPA 2022b). The FASOM model was used to estimate domestic impacts in the agricultural and forestry sectors, and the FAPRI model was utilized to model impacts in the international agricultural sector (EPA 2022b). The EPA's process for developing the modeling framework is discussed in Section 4.2.1.2 of the DRIA.

The DRIA utilizes a baseline scenario that the EPA describes as "No RFS." This baseline assumes that if there were no RFS volumes set by the EPA (2022a), production of ethanol would continue to occur in response to demand. Given that the EPA uses an integrated model that includes international and domestic impacts and a baseline that assumes market production of ethanol without the RFS, their modeling approach is aligned with that of Taheripour et al. (2022a) and the approach recommended by Austin et al. (2022).

Chapter 8 of the DRIA includes a table showing the EPA's corn price increase estimates for 2023, 2024, and 2025. Table 3-3 below is a duplication of Table 8.4-1 found in the DRIA. Note that the corn price increases shown in this table were estimated at $0.10/bushel for 2023 to 2025. This minimal impact in corn prices, although forward looking, is reflective of what Taheripour et al. (2022a) found when looking back at the time frame of 2004 through 2016 using an appropriate baseline. However, Taheripour et al.'s (2022a) results indicate even smaller impacts stating that real crop prices increased between 1.1 and 5.5% from 2004 to 2011 with only one-tenth of the price increases attributable to the RFS program, i.e. 0.11% and 0.55% respectively. Furthermore. Taheripour et al. (2022a), state that for the period 2011 to 2016, price impacts of biofuels were less than the period of 2004 to 2011, i.e., below 0.11% to 0.55% respectively.

**Table 3-3. Projected Impact on Corn Prices Relative to the NO RFS Baseline**

| Parameter | 2023 | 2024 | 2025 |
|---|---|---|---|
| Corn Price Percent Increase per Billion Gallons of Ethanol | 3% | 3% | 3% |
| Corn Price (RFS Volumes); $/bushel | $4.60 | $4.37 | $4.13 |
| Corn Price Increase per Billion Gallons of Ethanol; $/bushel | $0.14 | $0.13 | $0.13 |
| Corn Ethanol Increase; billion gallons | 0.706 | 0.776 | 0.84 |
| Corn Price Increase; $/bushel | $0.10 | $0.10 | $0.10 |
| Corn Price (No RFS Baseline); $/bushel | $4.50 | $4.27 | $4.23 |

Source: DRIA Section 8.4-1

Consistent with Taheripour et al. (2022a), the DRIA reports that impacts from other market factors could lead to a reduction of acres of corn planted, including a shift away from the usage of whole corn as animal feed with the rise of other substitutes (DRIA, pp. 406-407). According to the USDA, DDGS supply and use rises in concert with ethanol fuel production (Olson and Capehart 2019). As an approximately 1.22 to 1 by weight substitute for corn grain feed rations, DDGS can be a better alternative to corn due to a higher protein content and nutrient density (Wadhwa and Bakshi 2016). The EPA finds that an increase in DDGS is a factor contributing to the longer-term shift of the animal feed industry away from whole corn to increased use of DDGS, thus reducing the amount of corn that needs to be planted (DRIA, p. 407 ).

The DRIA discusses an important market factor that acts to balance corn prices within the market, that is the corn ending stock-to-usage ratio. Throughout the year, not all corn is used in production. Because corn is only harvested once a year, storage is a large contributor in the supply chain (DRIA, p. 409). What is left over is commonly referred to as corn ending stocks. The DRIA finds that there is a statistically significant negative correlation between the corn ending stock-to-usage ratio and corn futures prices (DRIA, pp. 409-411). This shows that the amount of corn stored at the end of the year has a dampening effect on price (DRIA, p. 409), which further supports that the RFS is not a main driver in corn production. Ramboll's analysis, which we provide in Section 3.3.3 and present in Figure 3-7, confirms EPA's findings that there is a statistically significant negative correlation between the corn ending stock-to-usage ratio and corn futures prices. In short, our analysis indicates that corn prices are minimally affected by the implied conventional volume and that corn acreage planted is offset by increased corn yield and DDGS.

## 3.3 Economic Analysis Methodology

### 3.3.1 Variables of Ethanol Industry

Based on industry research and interviews with small scale corn farmers and those who work in the ethanol industry, the primary factors that influence farmers' corn planting decisions by small farmers are futures prices, regular crop rotation, and soil health (EPA 2022c; USDA NASS 2023a)

Due to the interconnectedness of the corn production industry to other industries and dependence on environmental characteristics, attempting to account for each of these unpredictable variables will lead to a model that consists of too many assumptions which will not accurately represent the industry. To prevent introducing too many assumptions and variables into the model, we develop a series of simplified models to better illustrate which variables are or are not explanatory. In addition, the Ramboll models use observed data for evaluating market responses to factors such as the RFS or total ethanol production rather than attempting to simulate (i.e., forecast) market responses to such inputs or developing baseline simulations.

### 3.3.2 Analysis Objectives

Our analysis focuses on two primary objectives. The first is to evaluate the effect of the RFS and ethanol production on corn prices and acres of corn planted. The second is to evaluate which research efforts best represent the potential effect of the implied conventional volume on corn prices and corn acreage planted. We consider research performed by EPA (2022b) and others that obtained similar results and conclusions, such as those found by Taheripour et al. (2022a; 2022b; 2022c) in addition to results obtained by Lark et al. (2022).

Ramboll's analysis uses two primary analytical techniques: linear regression and the analysis of correlation coefficients. Linear regressions are commonly used in economics to establish empirical relationships between variables. Linear regressions can use either a single variable or multiple variables to identify the effect of one variable or a set of variables (i.e., explanatory variables) on the parameters of interest (i.e., dependent variables). The strength of the relationships between variables are described using regression coefficients. It is important to note that when performing linear regressions, relationships between variables are not necessarily causal. Linear regressions can describe causal relationships; however, these regressions require strong assumptions and a robust understanding of the underlying economic mechanisms (Verbeek 2017).

When interpreting regression coefficients, each slope coefficient measures the expected change in the dependent variable following a one-unit change in the explanatory variable of interest, maintaining all other explanatory variables constant (Verbeek 2017). There are several key statistics that measure whether the regression accurately represents the variables. Below is a list of the statistics we use in our analysis.

- $R^2$ – Also known as the coefficient of determination, is a statistical measure that indicates how well a regression model fits the data. It is usually interpreted as the percent of variation that is explained by the resulting regression equation. The closer $R^2$ is to one, the better the explanatory power of the regression.
- F-Statistic – This statistic is used to determine whether the relationship between the Y and X variables occurs by chance (null hypothesis) or is representative of an actual relationship (rejection of null hypothesis).
- T-Statistic – This value is used to determine if a statically significant relationship exists between the explanatory variables (e.g., RFS) and the dependent variable (e.g., corn prices).
- The correlation coefficient is a statistic that is used to determine the degree that one variable is related to another. It is a unitless index that ranges between -1 and +1. The closer this index is to -1 or +1, the greater the relationship.

An often-stated caution regarding the interpretation of correlation is that correlation does not equal causation. There are three reasons that we might observe a correlation between pairs of observed data.

First, a logical relationship does exist between the two variables. Second, there is another external factor that is affecting both variables. Third, the observed correlation has occurred purely by chance and no correlation exists. The second and third explanations of correlation represent the reasons for the often-stated caution regarding the use of this statistic.

Correlation is frequently used along with regression analysis to help evaluate if a dependency relationship exists between the explanatory parameters (the X values or independent values) and the parameter of interest (the Y value). Dependency means that a statistical relationship exists such that the independent values can be used to approximate the dependent value. Therefore, analysis of statistical results from linear regressions in conjunction with correlation is useful in evaluating the potential dependence between the variables of interest and reaching reasonable conclusions regarding this dependency.

### 3.3.3 Economic Analysis

This section details and depicts the economic models and relationships that were discussed in previous sections of this chapter. To start with the simple relationships, we run a regression of acres of corn planted versus corn futures prices to determine if futures prices have a significant influence on farmers' decisions. January futures were used for this analysis because they would be considered by farmers when making corn planting decision.

Figure 3-4 below presents the analysis between corn acres planted and January corn futures prices.

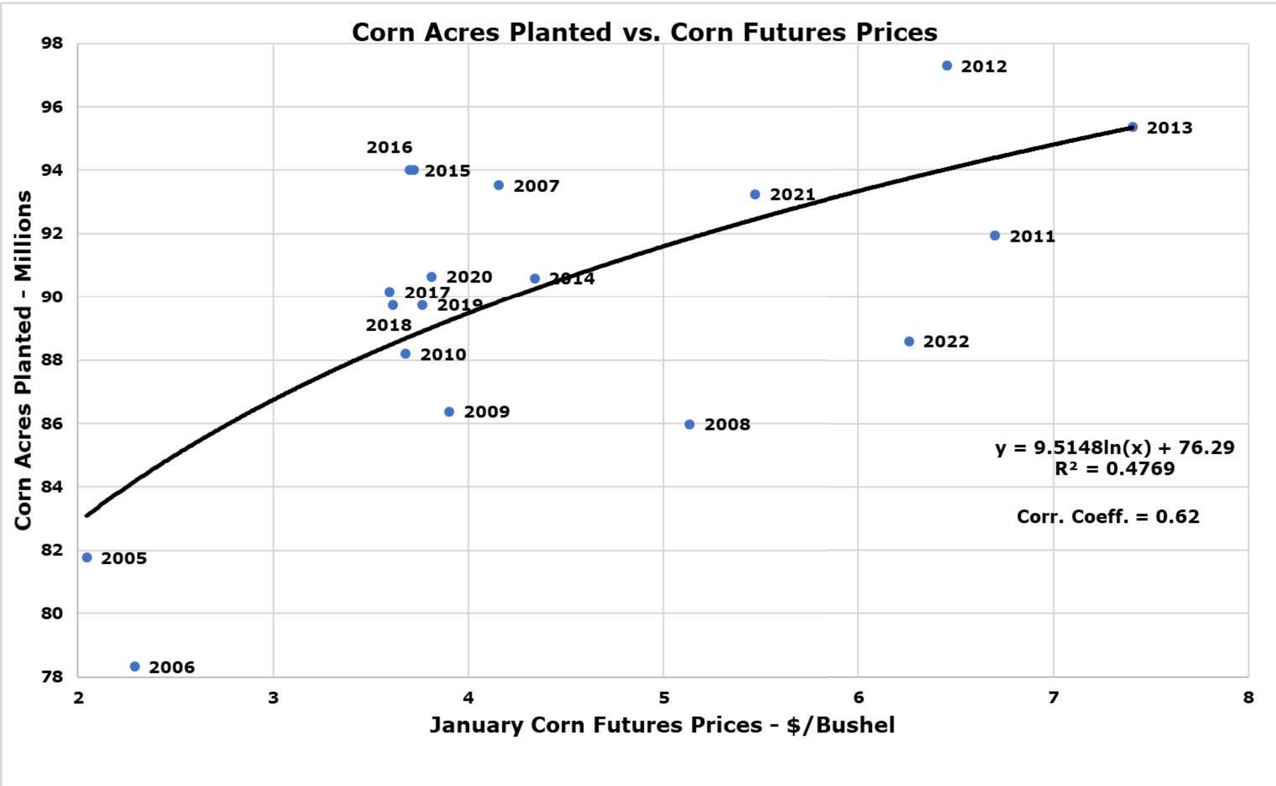



**Figure 3-4. Relationship Between Acres Planted and Futures Prices**

Data Sources:

Futures Prices – Macrotrends 2022

Corn Acres Planted – USDA NASS 2023a

**Interpretation**: Based on the outcome of the regression, a moderate statistical dependency exists between corn acres planted and January corn futures prices. However, the January corn futures prices explain less than 50% of the variation in corn acres planted. This shows that futures prices have a significant impact on planting; however, there are other factors not included in this model that may better explain price changes.

An argument made by Lark et al. (2022) was that the RFS program causes an increase in corn prices. Figure 3-5 below shows the lack of a statistical relationship between corn prices and the implied conventional volume[6]. A single variate regression is run to display the possible relationship.

[6] Our analysis does not account for small refinery exemptions (SREs). Accounting for the effect of SREs would lower the implied conventional volume although not significantly. Not including the impact of SREs makes our model more conservative in that it assumes a larger number for the implied conventional volume.

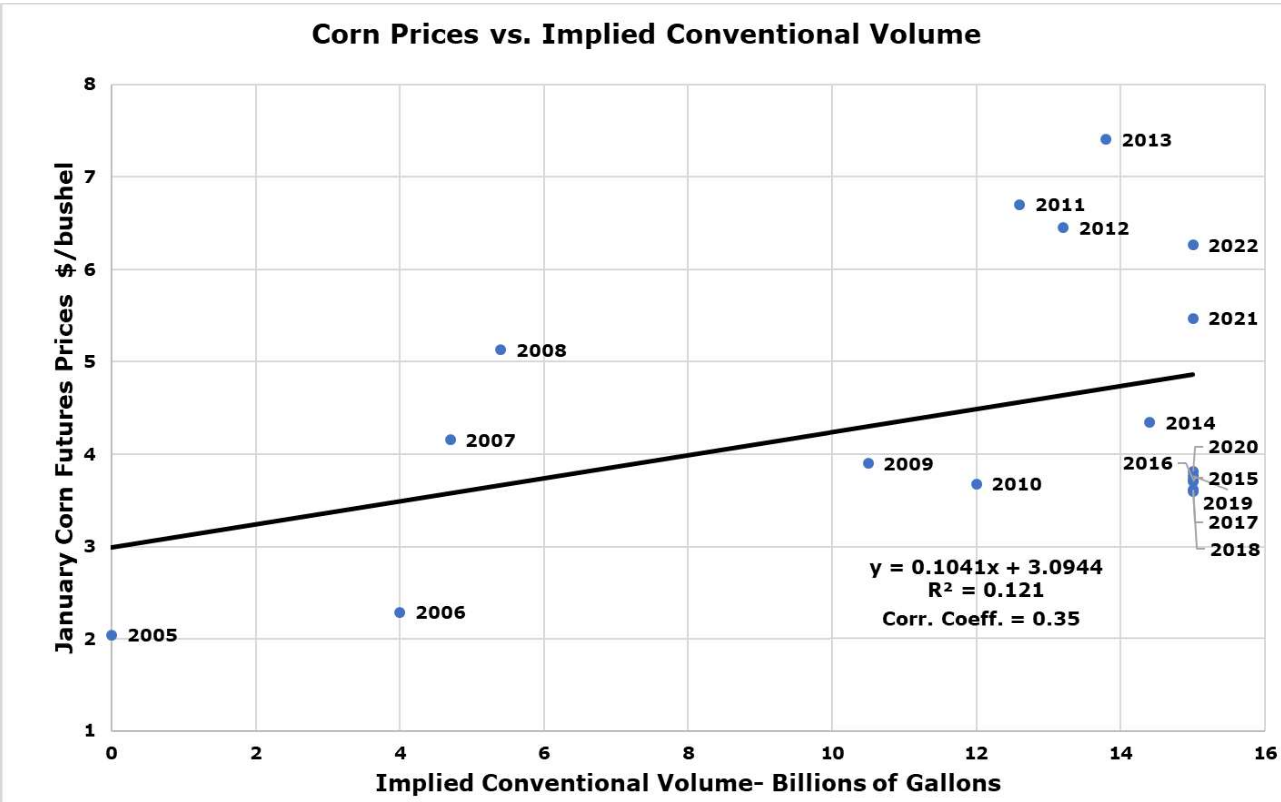



**Figure 3-5. Relationship Between Corn Prices and the Implied Conventional Volume**
Data sources:
Corn Prices – Macrotrends 2022
Implied Conventional Volume – EPA 2022c

**Interpretation**: Based on the results of the regression shown in Figure 3-5, the statistical dependency between corn prices and implied conventional volume is either non-existent or very weak, with an $R^2$ of 12%. As is clear in the figure, corn prices fluctuate widely by year and are not statistically dependent on the RFS. Reasons for price increases since 2005 could be inflation, prices of other commodities, and demand for corn in other industries, which are not displayed in this model.

Next, Ramboll tests the theory that ethanol production causes an increase in corn futures prices by running a single variate regression with ethanol plant production and January corn futures prices. In the following models, we use ethanol plant production values from the previous year's production volumes reported in December of the previous year, which likely have a closer relationship with January corn futures prices for the following year (i.e., the next month), assuming such a relationship exists.

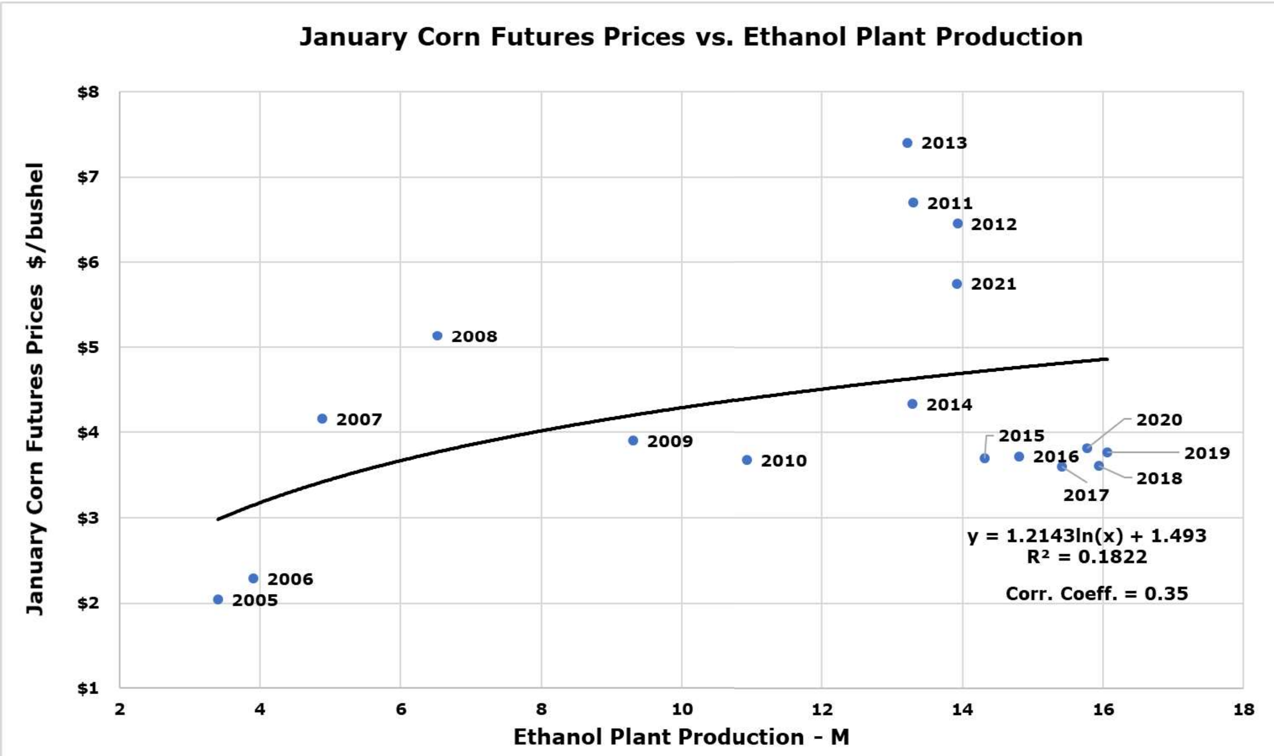



**Figure 3-6. Relationship between Corn Futures Prices and Ethanol Production**

Source Data:

January Futures Prices - Macrotrends 2022

Ethanol production – Alternative Fuels Data Center 2021

**Interpretation:** The results show a statistical dependency between corn prices and ethanol plant production is either non-existent or very weak based on the small $R^2$ value of approximately 18%. This $R^2$ value and Figure 3-6 indicate that corn prices do not fluctuate in relation to ethanol production. There could be various reasons for this weak relationship including the corn ending stock-to-use ratio (see Figure 3-7).

As stated by the research (DRIA) and supported by industry trends, a statistical dependency exists between corn ending stock-to-usage ratio and corn prices. Therefore, we perform an analysis to test this relationship and present it as Figure 3-7 below.

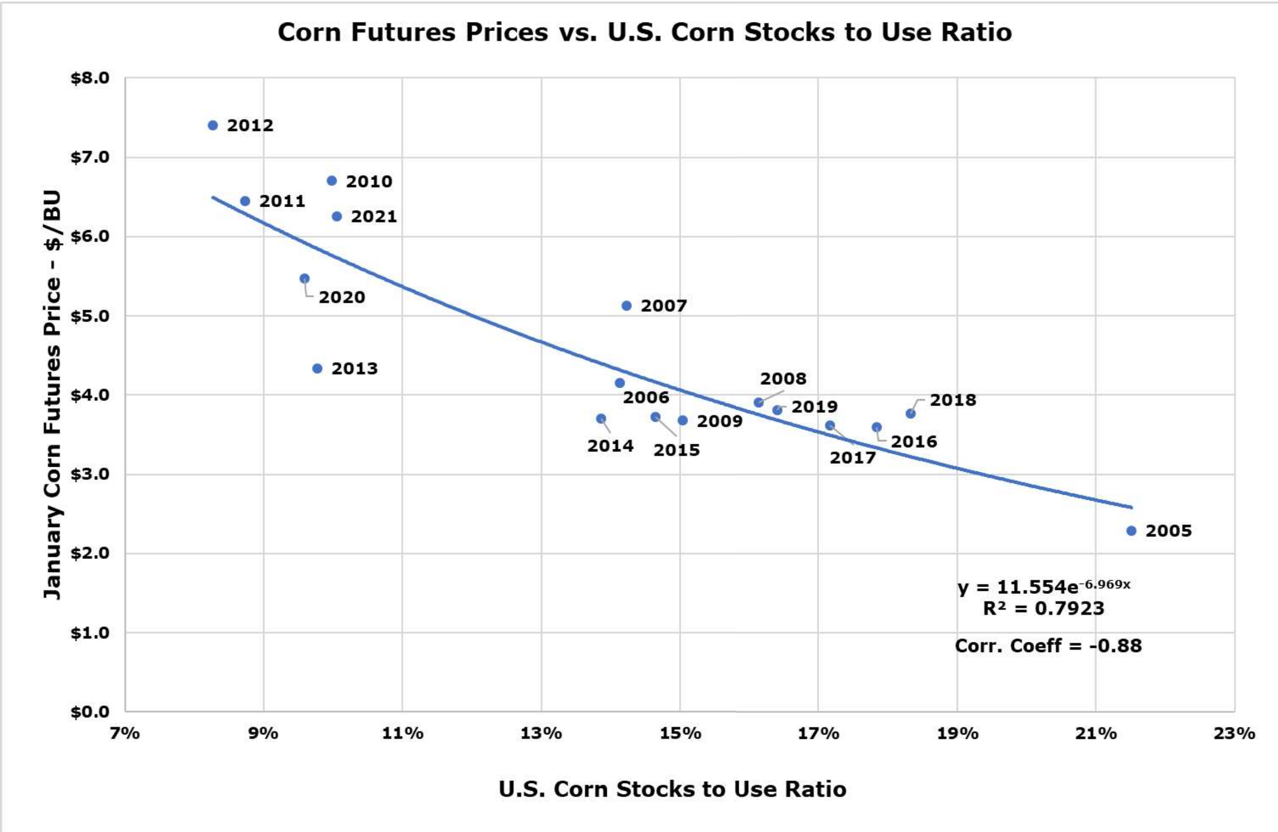



**Figure 3-7. Relationship between Corn Futures Prices and Corn Stocks to Use Ratio**

Data sources:

Corn Futures Prices – Macrotrends 2022

Con Stocks – Index Mundi 2023

**Interpretation:** As the results in Figure 3-7 indicate, corn futures prices are statistically dependent on the corn ending stock-to-use ratio, with an $R^2$ of nearly 80%. The trendline also fits the data relatively well.

We next run a regression including the implied conventional volume and acres of corn planted to test whether the acres of corn planted is statistically dependent on the implied conventional volume.

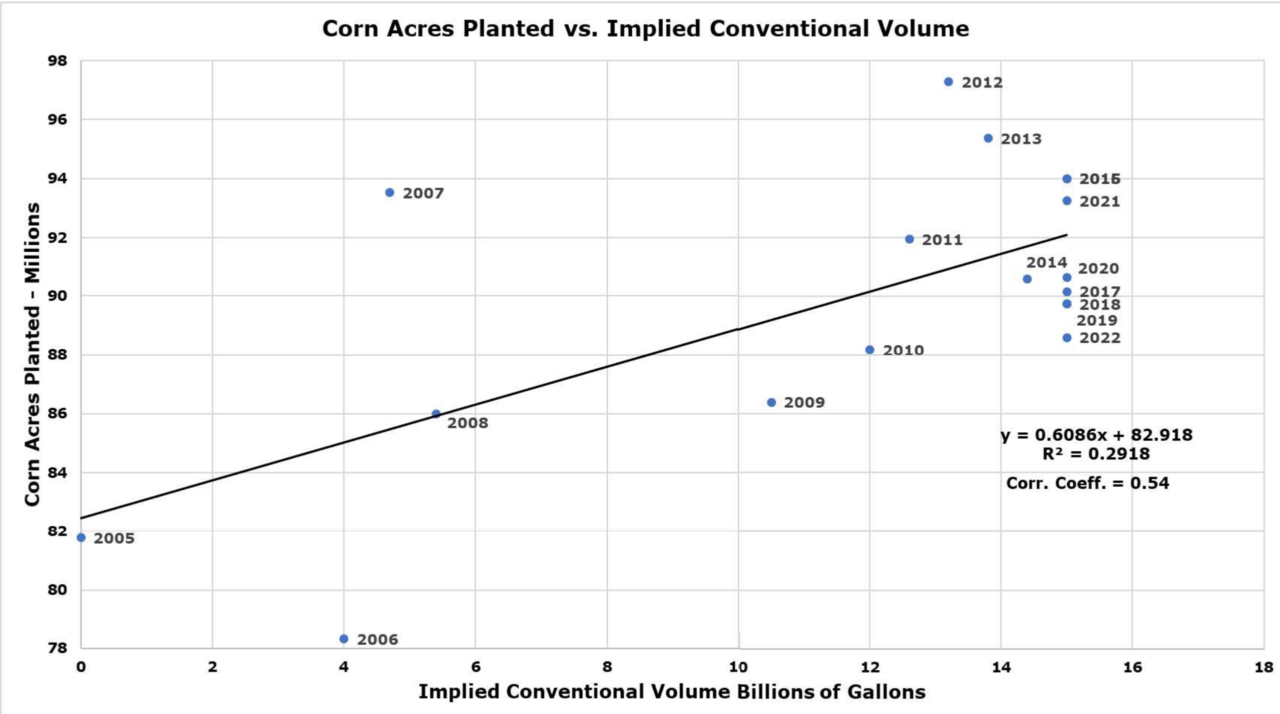



**Figure 3-8. Relationship between Corn Acres Planted and the Implied Conventional Volume**

Data sources:

Corn Acres Planted – USDA NASS 2023a

Implied Conventional Volume – EPA 2022c

**Interpretation**: As the figure and the $R^2$ value of less than 30% show, a weak statistical dependency may exist between the corn acres planted and the implied conventional volume.

Next, we run a single variate regression to determine if there is statistical dependence between the ethanol production quantities and acres planted of corn.

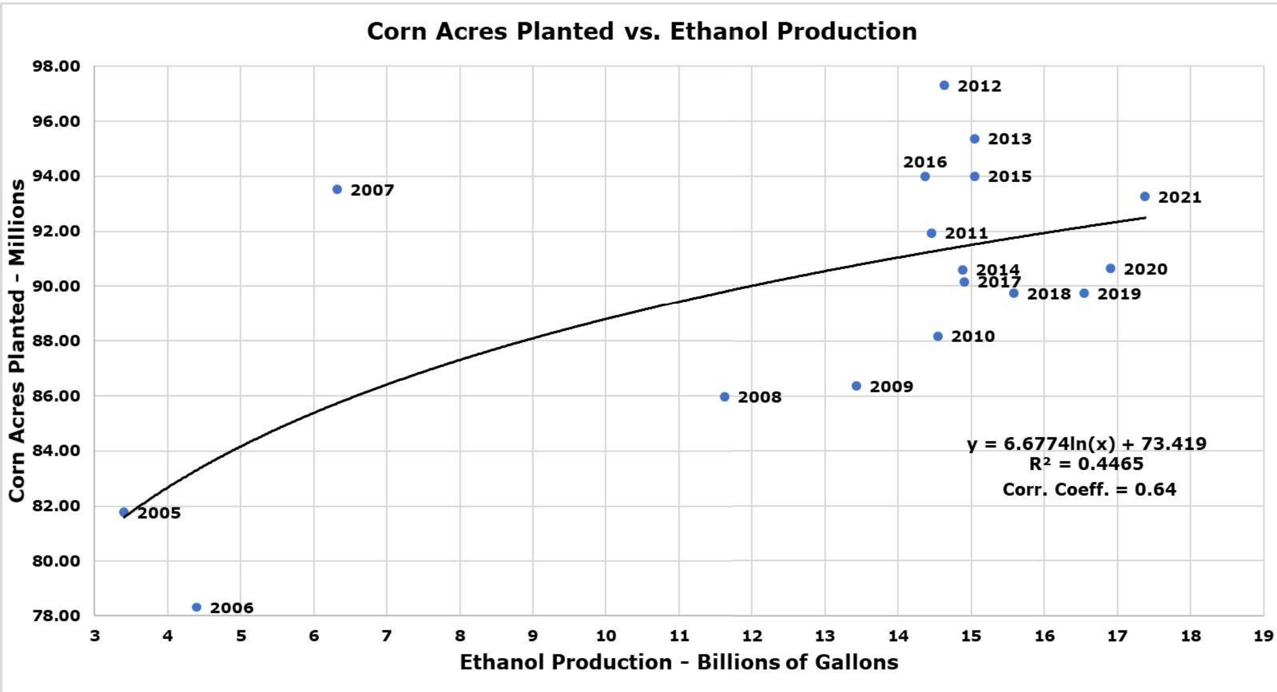



**Figure 3-9. Relationship Between Corn Acres Planted and Ethanol Production**

Data sources:

Corn Acres Planted – USDA NASS 2023a

Ethanol Production – Alternative Fuels Data Center 2021

**Interpretation**: Figure 3-9 demonstrates a weak to moderate statistical dependency may exist between the corn acres planted and the ethanol production, with an $R^2$ value of approximately 45%. However, when we consider the analysis of the multivariate regression performed for corn acres planted, this dependency is found not to be significant when accounting for other explanatory parameters (i.e., wheat prices, soybean prices, and corn ending stock use ratio) as a group. This demonstrates why single variate regressions, although potentially informative, must be considered in conjunction with other potentially explanatory parameters.

Our next regression involves analyzing the relationship between corn prices and crude oil prices. This analysis is performed because crude oil is known to be a supply chain cost for corn cultivation.

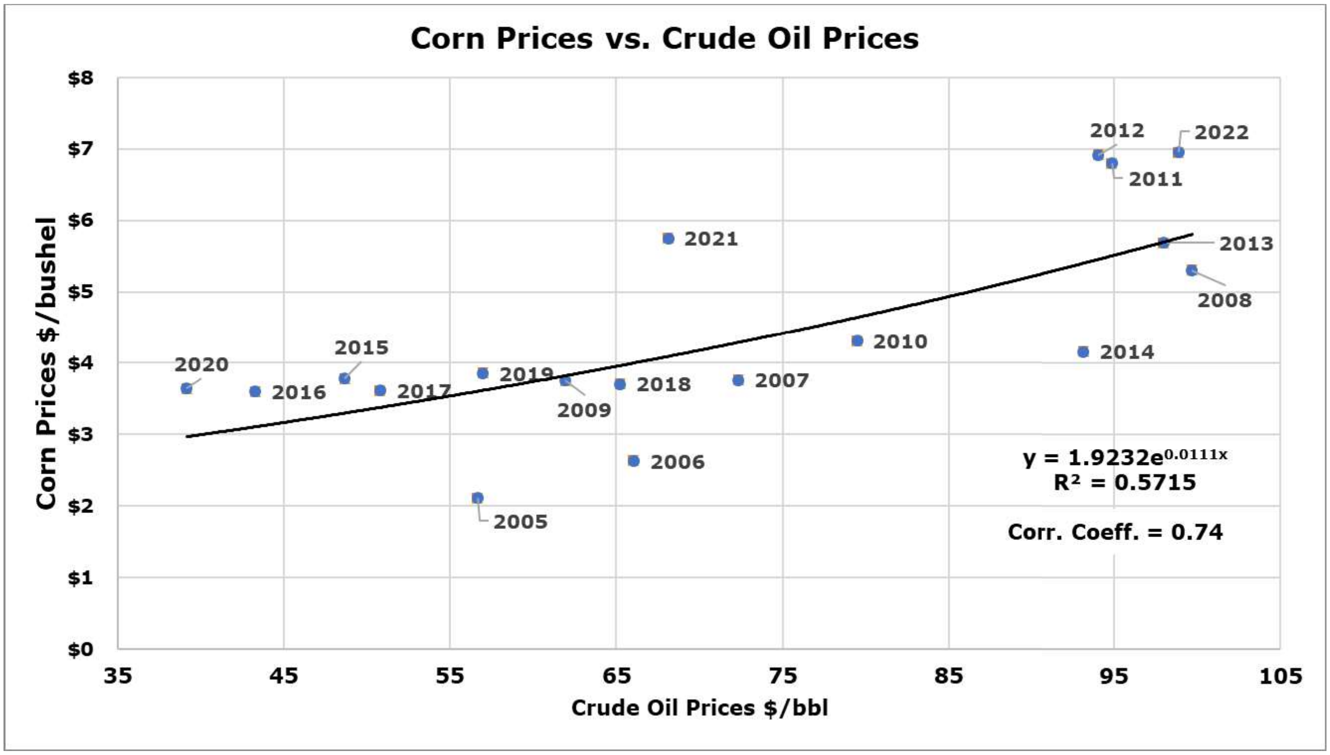



**Figure 3-10. Relationship Between Corn Prices and Crude Oil Prices**

Data sources:

Corn Spot Prices – Macrotrends 2022

Crude Oil Spot Prices – US Energy Information Administration 2023

**Interpretation:** Based on Figure 3-10, crude oil spot prices have a moderate statistical significance on corn prices, with an $R^2$ value of 57%. Due to the moderate level of statistical significance, crude oil prices were included in a multivariate regression; however, it did not present as statistically significant. When included in a multivariate regression, the regression coefficient showed that for every dollar increase in crude oil prices, there is a one cent increase in the price of corn per bushel. Additionally, the inclusion of crude oil removed the statistical significance of other variables, such as soybean prices, which as previously discussed, are known to be an explanatory variable for corn prices. As such, crude oil prices were not included in the final multivariate regression.

Figures 3-4 through 3-10, presented above, present simplistic models to demonstrate that implying one factor is the driving force behind an increase in corn prices and corn planting patterns is simply unrealistic[7]. The two main assumptions made by Lark et al. (2022) were that the volumes established by the RFS program will directly increase the demand for corn, which will increase corn prices and the overall acres of corn planted. To provide a more realistic analysis that considers the effects of groups of

[7] An area we did not investigate is the relationship between D4 renewable identification numbers (RINs) and D6 RINs as they are related as part of the overall program. However, our opinion is that the relationship between these potentially explanatory variables, in particular the effect of D4 RINs on corn prices and corn acreage is better addressed by investigating whether soybean prices are statistically dependent on biobased diesel volume requirements, and in turn does any effect on soybean prices impact corn prices and corn acreage. This analysis was performed, and the answer is that corn prices and acreage have a non-existent to weak statistical dependency with biobased diesel standards and production. This analysis is presented on page 31.

potentially explanatory variables, we run two multivariate regressions, one for corn prices and the other for corn acres planted. As presented below, both these multivariate regressions indicate that the implied conventional volume and ethanol production have minimal to no effect on corn prices or corn acres planted.

The explanatory parameters selected for each regression are chosen because they fit one of the following categories:

1. Evaluations of previous single variate regressions and correlation coefficients indicate that corn prices or corn acres planted are statistically dependent on these parameters. For example, corn prices have been shown to be statistically dependent on ending corn stocks-to-usage ratio (Figure 3-7) and corn acres planted have been shown to be statistically dependent on corn futures prices (Figure 3-4).
2. General industry acceptance that certain parameters influence corn prices or corn acres planted (i.e., both soybean prices and wheat prices are generally accepted to influence corn prices and corn acres planted due to natural crop rotations [Camp 2019]).
3. Assertions by Lark et al. (2022) and others that corn prices and acres planted are attributable to certain parameters, i.e., the RFS and ethanol plant production.

We include the following potential explanatory parameters in our multivariate regression for corn futures prices based on the above criteria: implied conventional volume (billions of gallons), ethanol plant production (billions of gallons), January wheat futures price ($/bushel), January soybean futures price ($/bushel), and corn ending stock use ratio (%). Table 3-4 below presents the results of the regression.

**Table 3-4. Corn Futures Prices Regression**

| | **Constant, $b_0$** | **Implied Conventional Volume, $b_1$** | **Ethanol Plant Production (Prev. Yr.), $b_2$** | **January Wheat Futures Prices, $b_3$** | **January Soybean Futures Prices, $b_4$** | **Corn Ending Stock Use Ratio, $b_5$** |
|---|---|---|---|---|---|---|
| Regression Coefficients | 2.03 | -0.21 | 0.19 | 0.14 | 0.34 | -12.78 |
| T-Statistic | 1.68 | -1.33 | 1.21 | 0.70 | 2.37 | -2.51 |
| T-Critical | 2.20 | -1.80 | 2.20 | 2.20 | 2.20 | -1.80 |
| Significant | No | No | No | No | **Yes** | **Yes** |
| R-Factor | **0.89** | --- | --- | --- | --- | --- |
| F-Statistic | **17.36** | --- | --- | --- | --- | --- |
| F-Critical | 3.01 | | | | | |

The first row of this table provides the regression coefficients. In the column heading these coefficients have been designated $b_1$ through $b_5$. In addition, note that there is a constant term designated $b_0$. These coefficients represent multipliers used (along with the constant factor) in an equation for estimating corn futures prices (i.e., y value) as follows.

$$y = b_0 + b_1(RFS) + b_2(Eth.Prod.) + b_3(wheat\ fut.) + b_4(soybean\ fut.) + b_5(corn\ stock\ end\ ratio)$$

In terms of the actual coefficients reported in Table 3-4 this equation becomes:

$$y = 2.03 - 0.21(RFS) + 0.19(Eth.Prod.) + 0.14(wheat\ fut.) + 0.34(soybean\ fut.) - 12.78(corn\ stock\ end\ ratio)$$

In other words, we now have the equation of a line that is like the lines presented within Figures 3-4 through 3-10, with the exception that it is multidimensional and therefore impossible to graph. Now that the equation of this line has been determined, the question becomes, does it represent a reasonable or valid model? To answer this question, we return to our previously described $R^2$, F-Statistic, and T-Statistic to interpret these results.

**Interpretation:** The $R^2$ value associated with our model is 0.89, which tells us that nearly 89% of the variability in corn futures prices is explained by the regression model.

The F-Statistic of 17.36 is greater than F-Critical of 3.01, which indicates that we can reject null hypothesis that the relationship between Y's and X's occurs by chance. In other words, based on the comparison of the F-Statistic and F-Critical we can state that the relationship between our explanatory variables and our dependent variable (corn futures prices) does not occur by chance.

Analysis of our T-Statistic versus their associated T-Critical values indicates only two of the explanatory variables are statistically significant, i.e., soybean futures prices and the corn ending stock-use-ratio. These findings are consistent with the nature of the industry and discussions with industry professionals, as Figure 3-11 below further supports. The coefficient for the corn ending stock use ratio tells us that if all other variables were held constant, for every percent increase of the ending stock-use-ratio, the corn price decreases by nearly $0.13 (i.e., 0.01 x -12.78 = -0.1278). For every dollar increase in soybean prices, there is a $0.34 increase in corn prices.

We now turn our attention to the other remaining explanatory parameters that, according to the T-test, were determined not statistically significant. When an explanatory variable is not statistically significant, we cannot reject the null hypothesis associated with this T-test that these regression coefficients are zero. In other words, although we have a valid regression based on the F-Statistic test and the $R^2$ we cannot be certain that the coefficients for wheat futures, ethanol production, and RFS are not zero. In other words these coefficients may be zero. Therefore, the implied conventional volume and ethanol production are not significant contributors to corn prices. This multivariate analysis provides additional evidence that ethanol production and the implied conventional volume have minimal or no effect on corn prices.

Since the multivariate regression for corn prices indicates soybean prices are significant, we perform further analysis of corn prices versus soybean prices. Figure 3-11 presents the results, which indicate a statistical dependency exists between corn and soybean futures prices.

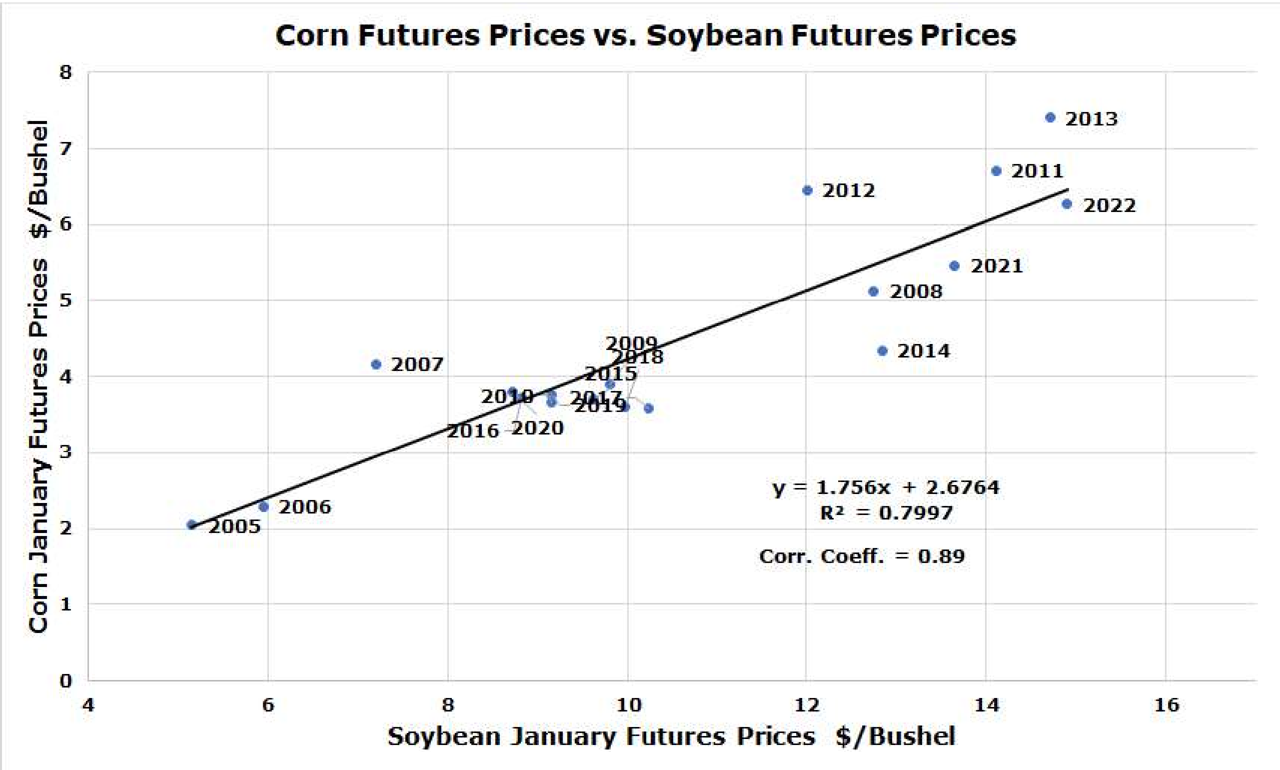



**Figure 3-11. Relationship Between Corn Futures Prices and Soybean Futures Prices**

Data sources:

Soybean Futures Prices – Macrotrends 2023

Corn Futures Prices – Macrotrends 2022

This provides an additional confirmation that soybean prices should be included as an explanatory variable in the multivariate regression for corn prices.

Having determined that soybean prices are a significant explanatory parameter regarding corn prices, we ran two more single variate regressions. The first to determine if soybean prices are statistically dependent on the biomass-based diesel (biodiesel) volume standard. The second to determine if soybean prices are statistically dependent on biodiesel production. The first regression resulted in an R-Factor of 0.03 and a correlation coefficient of 0.19 thus indicating that soybean prices are not statistically dependent on the biodiesel volume standard. The second regression resulted in an R-Factor of 0.18 and a correlation coefficient of 0.42 thus indicating that there is a weak statistical dependency between soybean prices and biodiesel production. This result led to the decision to perform one more single variate linear regression to determine if corn prices are statistically dependent on biodiesel production. This last single variate regression resulted in an R-Factor of 0.18 and a correlation coefficient of 0.25. These results indicate that there is a very weak to non-existent statistical dependency between biodiesel production and corn prices. Based on the results of this this last single variate regression, Ramboll determined that there is no need to update the multivariate linear regression for corn prices to include biodiesel production.

We run a second multivariate regression to assist with more clearly understanding which variables may be explanatory for corn production. This regression includes implied conventional volume; ethanol production; January corn, wheat, and soybean futures prices; and the corn ending stock-to-usage ratio. We utilize the same thought process and econometric principles to attain the equation of a line for corn plantation in acres.

**Table 3-5. Corn Production Regression**

| | **Constant, $b_0$** | **Implied Conventional Volume, $b_1$** | **Ethanol Plant Production (Prev. Yr), $b_2$** | **January Corn Futures Prices, $b_3$** | **January Wheat Futures Prices, $b_4$** | **January Soybean Futures Prices, $b_5$** | **Corn Ending Stock-to Usage Ratio, $b_6$** |
|---|---|---|---|---|---|---|---|
| Regression Coefficients | 72.74 | 1.20 | -0.53 | 5.12 | -0.42 | -1.55 | 41.04 |
| t* | 11.87 | 1.54 | -0.68 | 3.76 | -0.44 | -1.97 | 1.42 |
| T-Critical | 2.23 | 2.23 | -1.81 | 2.23 | -1.81 | -1.81 | 2.23 |
| Significant | **Yes** | No | No | **Yes** | No | **Yes** | No |
| R-Factor | **0.81** | --- | --- | --- | --- | --- | --- |
| F-Statistic | **7.22** | --- | --- | --- | --- | **---** | --- |
| F- Critical | 3.14 | --- | --- | --- | --- | **---** | --- |

**Interpretation:** The $R^2$ value in Table 3-5 shows that 81% of the variability in corn production is explained by the model, which ensures this is a strong model.

The F-Statistic of 7.22 is greater than F-Critical of 3.14, which indicates that we can reject null hypothesis that the relationship between Y's and X's occurs by chance. Based on the analysis of our T-Statistic versus their associated T-Critical values, two of the explanatory variables show a statistical significance: corn futures prices and soybean futures prices.

Looking at the regression coefficients, we expect to see a statistically significant relationship between soybean futures prices and corn futures prices based on their use in the industry. Soybean is used to help maintain healthy nitrogen levels in the soil (making it a crop regularly rotated with corn) and is also used in biofuels, so it is often a crop that can also act as a substitute for corn. The statistical significance associated with the corn production acres indicates this model is a good representation of the industry. The regression coefficient for corn prices indicates that for every dollar increase in corn futures prices, corn acreage is expected to increase by 5.22 million acres. The regression coefficient for soybean prices indicates that for every dollar increase in soybean prices, corn acreage is expected to decrease by 1.55 million acres.

Table 3-5 shows that the corn ending stock ratio, wheat futures prices, ethanol production, and the implied conventional volume are all not statistically significant, so although we have a valid regression based on the F-Statistic test and the $R^2$, we cannot be certain that the regression coefficients of these parameters are not zero. Therefore, this multivariate analysis provides additional evidence that ethanol production and the implied conventional volume have minimal or no effect on corn acres planted.

### 3.4 Economic Results/Discussion

As we demonstrate by the models and figures in the preceding subsections, the implied conventional volume is not a driving factor of an increase in acreage of corn production and, by proxy, any potential negative environmental effects associated with same. Overall, we conclude that futures prices of soybeans and the year ending stock use ratio are statistically the strongest variables in this analysis for the change in corn futures prices. Based on our regressions, the strongest indicators for corn acreage quantities are soybean and corn futures prices.

A potential gap in these regressions is that seasonality is not included as a potential variable in the analysis and as discussed earlier, seasonality, weather, soil health, and pest control are all crucial factors in planting decisions.

A difficult component to econometrics is the balance between including enough explanatory parameters in a model without over complicating it and clouding the model with variables that hold no statistical significance. Typically, adding parameters can improve an $R^2$ value even if not all the parameters are found to be significant. This can happen because even though these parameters are not statistically significant, they still have some influence. Lark et al. (2022) may have overcomplicated their model by adding two different time periods and non-representative resolution data, while also making implausible forecasts (as discussed throughout this report) resulting in misleading results that the RFS was directly contributing to LUC and price increases in crops.

Overall, our research concludes that the studies conducted by the EPA (2022b), Taheripour et al. (2022a), and Austin et al. (2022), are more representative of the likely effects of the implied conventional volume and ethanol production on corn prices and corn acres planted than are the results of Lark et al. (2022). The methods used by the EPA (2022b) and Taheripour et al. (2022a) account for effects of the global and domestic economies. The methods we use in this report, although high level, are based on 18 years of observed data. The results of our analysis confirm that the implied conventional volume has minimal to no effect on corn prices and acres of corn planted, consistent with the work by the EPA (2022b) and Taheripour et al. (2022a).

## 4. Environmental and Ecological Analysis

We support EPA's finding that although some degree of LUC has been "ascribed to biofuel production, and in some cases even to the RFS program itself, in reality, such **a causal connection is difficult to make with confidence**" (DRIA, p. 240) (emphasis added). These findings were originally presented in EPA's Second Triennial Report to Congress (EPA 2018). In fact, recent publications (e.g., Taheripour et al. 2022b), as well as Ramboll's independent analysis described above, demonstrate that any causal relationship between the RFS and LUC is weak at best, and likely results in very small changes in land use as compared to studies previously reviewed by EPA. This newer understanding of the relationship between LUC and the RFS is pivotal to discussions of potential adverse effects to wetlands, other ecosystems, and wildlife and should be acknowledged by EPA throughout the associated section in the final RIA.

## 4.1 Land Use Change References

This section addresses the references made by EPA to LUC throughout the RFS and DRIA (EPA 2022a; 2022b). This topic merits special review because LUC in the form of agricultural extensification has garnered much attention when it comes to assessing the potential impacts of the RFS on land and water. Agricultural extensification may result in impacts to water quality and water supply, soil quality, and habitat loss and consequent impacts to wildlife (including sensitive and special status species). Some investigators claiming widespread LUC is due to the RFS (e.g., Johnston 2013; Lark et al. 2015; 2022; Wright et al. 2017) are heavily cited in the DRIA even though the EPA found that "in reality, such a causal connection is difficult to make with confidence" (DRIA, p. 240). We support the EPA's assertion that there is no clear causal link given the evidence shown in recent papers that results by Lark et al. (2015; 2022), Wright et al. (2017), and Johnston (2013) appear to have overestimated the magnitude of extensification due to critical methodological flaws (Copenhaver 2022; Dunn et al. 2017; Pritsolas and Pearson 2019; Shrestha et al. 2019; Taheripour et al. 2022b; USDA 2022). None of this recent literature, further discussed below, is cited in the DRIA. We recommend these more recent studies should be added to the final RIA give a more balanced understanding of LUC. Select findings from these recent papers are highlighted below.

1. Taheripour et al. (2022b) "Environmental Outcomes of the U.S. Renewable Fuel Standard" made the following observations regarding Lark et al.'s (2022) estimates of LUC:

    - Increases in corn yield and the offsetting effects of DDGS were inadequately considered.
    - High-end yield increases in 2008 corn acres more than compensate for the increase of 5.5 billion gallons of ethanol assumed by Lark et al. (2022).
    - Ethanol demand may not drive an expansion above the 2008-year corn footprint.
    - Many parcels in the "Cropland Expansion Layer" appeared to be land that is periodically oscillating between agriculture and a fallow state rather than representing long-term extensification.
    - The time period assessed, 2008 to 2016, corresponds to a period of large increases in crop prices which are not attributable solely to biofuels and represents only a short time period as compared to the long-term RFS policy. This temporally biased attribution can result in an overestimate of the magnitude of LUC potentially attributable to the RFS.

2. USDA (2022) found that conclusions by Lark et al. (2022) regarding carbon losses per acre potentially associated with the RFS likely overestimated actual losses by a factor of ten. USDA (2022) identified the following major flaws in the work that are related to estimates of LUC:

    - Failure to account for cropland-to-cropland conversions including land that is moving between corn and other row crops, which may include crop rotations to improve soil health.
    - Misclassification of Conservation Reserve Program (CRP) land as either native lands or longer-term CRP lands.
    - Failure to account for geographic heterogeneity in the demand for corn for ethanol that is driven by the location of ethanol refineries. Instead, Lark et al. (2022) allocated their LUC estimates equally within the study's boundaries.
    - The title of the Lark et al. (2022) paper implies that the findings are causally linked to the impact of the RFS on corn, soybean, and wheat prices. However, the authors modeled the impact on corn prices from corn ethanol demand in general, and this demand was not exclusively influenced by

the RFS. Other major drivers for corn ethanol demand include substitution of corn ethanol for MTBE following the ban of MTBE and increases in oil and gasoline prices.

3. Copenhaver (2022) analyzed many data sources, including aerial imagery, to determine whether the moderate resolution databases used to calculate LUC were accurate. He found that the CDL data layer that Wright et al. (2017) and Lark et al. (2015; 2021) relied upon was unreliable for correctly estimating LUC. Even Lark et al. (2021) report that accuracies for identifying noncropland classes using the CDL data layer can be as low as 50%. Specifically, Copenhaver (2022) had the following findings:

   - "[…]Datasets classified [by CDL] as natural-to-crop land change was idle cropland."
   - Even at a resolution of 30 meters, sufficient granularity to observe change in small plots of land was lacking, and it became increasingly difficult to accurately identify land cover types with larger resolutions.
   - "Moderate resolution satellite imagery is hindered by low accuracies for noncropland classes and limited land cover/use classes."
   - Number of hectares changing to cropland (7,901) was similar to the number of hectares returning to grassland (6,145) after a detailed analysis of counties showing change in hectares farmed.

4. Pritsolas and Pearson (2019) reviewed the research methodologies for the LUC assessments published by Wright and Wimberly (2013), Lark et al. (2015), and Wright et al. (2017). All three of these publications relied on the CDL for their analyses. Some of the main points from their review included:

   - Low accuracy in the CDL for "native prairie, Conservation Reserve Program, grass hay, grass pasture and fallow/idle grasslands."
   - Increased accuracy in the CDL over time due to improving technology which could lead to wrongful findings of LUC. For example, the 2012 CDL was nearly 100% accurate in classification of acres of corn and soybeans, but only 80% accurate in 2008. Therefore, land that was crops in 2008 but was misclassified as natural area would have falsely appeared to have changed to crops in 2012.
   - A net increase of 38,000 acres of cropland, compared to the 263,468 acres found by Lark et al. (2015) or the 295,100 acres reported by Wright et al. (2017) after a close examination of Iowa LUC between 2008 to 2012 using the USDA NASS.

5. Dunn et al. (2017) conducted an analysis of LUC in the Prairie Pothole Region using CDL data, modified CDL data, data from the National Agricultural Imagery Program, and ground-truthing. They found many sources of error when relying only on the CDL. Specifically, they found the following:

   - The CDL and modified CDL analyses vastly overestimated LUC in the Prairie Pothole Region.
   - The CDL and modified CDL analysis did not find land clearing for agriculture when it was less than the 30-meter resolution of the CDL.
   - Areas with more diverse types of land cover and that were less often planted with the same row crops had higher errors in CDL and modified CDL classifications.
   - Topographical features increased the error in CDL and modified CDL classifications.

6. Shrestha et al. (2019) "manually verified" CDL data classification in 664 square kilometers in three areas in the US to determine whether there was a possible link between biofuel production and LUC. They found that automated land classification systems were not effective at accurate estimations of LUC and cited the Lark et al. (2015) paper as one that overestimated LUC because it relied on the CDL. They concluded:

   - LUC to cropland in the areas examined between 2011 to 2015 was 8.53% using CDL data, while manual verification showed only 0.31% change.
   - Land classification systems automated by the CDL and National Land Cover Database were not designed to calculate LUC.
   - Data distributed spatially in the CDL were not official data. Official data was available, but only when aggregated at the county level.

The above listed papers criticized the methods of Lark et al. (2015; 2022), and Wright et al. (2017). However, their criticism is also apt for Johnston (2013). The DRIA refers to Johnston (2013) as potential evidence for wetland loss in the Prairie Pothole Region. Like Lark et al. (2015; 2022) and Wright et al. (2017), Johnston (2013) used the CDL in her LUC analysis by intersecting this layer with the US Fish and Wildlife Service's National Wetland Inventory (NWI) data layer. Not only is the CDL a poor tool for estimating accurate LUC to crops, the NWI layer is also unreliable. As indicated by US Fish and Wildlife Service (2023), the NWI is a planning-level tool that makes "no attempt to define the limits of proprietary jurisdiction," and includes no measure of ground-truthing. Therefore, the NWI is not a robust dataset for estimating wetland loss at a scale as far-reaching as that of the entire Prairie Pothole Region. Furthermore, the analysis of Johnston (2013) did not compare findings from before and after 2008 and provided no acceptable reference or counter-factual scenario for how things may have evolved in the absence of the RFS. Johnston (2013) cited increased demand for corn to produce ethanol as the reason for potential extensification, however her causal analysis lacked rigor. Johnston (2013) did not assess the causal linkage except by association to corn prices. This assumption is erroneous, as we have shown in our economic analysis that there is little direct association between corn prices and demand for ethanol or the RFS volumes.

In summary, to the extent any LUC is driven by US biofuels policy, such change has not been quantified in a predictable and repeatable manner and observed change has not been causally linked to biofuels policy. Nor is there any evidence that LUC will result from the volumes proposed in the current rule. The final RIA should comprehensively address the limitations of the Lark et al. (2015; 2022), Wright et al. (2017), and Johnston (2013) papers or remove citations to them. Additionally, we recommend that the EPA include references to the following articles: Copenhaver 2022; Dunn et al. 2017; Pritsolas and Pearson 2019; Shrestha et al. 2019; Taheripour et al. 2022b; USDA 2022 to clearly explain the shortcomings in the methodologies that have been used to predict LUC, and to acknowledge the studies that conclude that the causal relationship between the RFS and LUC is weak or non-existent.

## 4.2 Conversion of Wetlands, Ecosystems, and Wildlife Habitats

This section of the report references Section 4.3 in the DRIA: Conversion of Wetlands, Ecosystems, and Wildlife Habitats.

### 4.2.1 Wetlands

The DRIA states that "[it] does not provide the information needed to determine the portion of wetland acres lost in order to grow feedstocks for biofuels, nor does it attempt to identify the portion of lost wetland acres attributable to the RFS program," (DRIA, p. 242) and further, repeats the acknowledgement in the second Triennial report that EPA cannot quantify the amount of cropland extensification that may have been due to the market for biofuels (and by extension any increased demand for corn for ethanol due to the RFS). These statements require qualification because the literature does not support that there is any wetlands loss attributable to the RFS. In addition, many investigators have suggested that the RFS results in extensive wetland loss, without adequate support. Unfortunately, technical flaws in literature the DRIA cites to show wetland loss due to agricultural extensification (Wright et al. 2017 and Johnston 2013) make the authors' assessments unreliable. These papers use CDL data to create their estimates, which, according to literature we cited in Section 4.1, suggests that they grossly overestimate wetland LUC. They also do not provide a quantitative causal framework for attributing estimated wetland loss to the RFS rule specifically.

Furthermore, Wright et al. (2017) and Johnston (2013) implied that the decision by individual farmers to extend their agricultural land at the expense of wetlands is a simple decision based largely on increased corn prices driven by the RFS. However, our economics section demonstrated that the decision is not simple and that factors apart from corn prices are critical to a farmer's decision. In addition to typical agricultural factors such as soil health and projected profits, there are also many policy provisions in place to reduce the occurrence of wetland conversion due to agricultural extensification. Incentive programs (as outlined by Gleason et al. 2011) included in the Farm Bills such as the Wetland Reserve Program in the 1990 Farm Bill[8] and the Wildlife Habitat Incentives Program and Environmental Quality Incentives Program in the 1996 Farm Bill[9] discourage agricultural extensification by providing financial incentives to a farmer for preserving sensitive ecosystems, such as wetlands. Further, the Swampbuster provisions, included in the Food Security Act of 1985 (Public Law 99-198), deem a farmer ineligible for certain USDA benefits (subsidies, loans, crop insurance, etc.) if agricultural commodities are produced on converted wetlands. Conversion of wetlands is not only decided by the decision of an individual farmer but is also heavily regulated under Section 404 of the Clean Water Act (33 US Code § 1344), which can require extensive permitting, and often compensatory mitigation, for impacts to wetlands greater than 0.1 acres. These mitigating factors and incentive programs are additional factors in a farmer's decision to pursue wetland conversion in favor of agricultural extensification and should be explicitly acknowledged in EPA's final RIA.

### 4.2.2 Other Ecosystems

The DRIA section on conversion of other ecosystems is largely focused on the conversion of grasslands and the EPA cites Wright et al. (2017) and Lark et al. (2015) as the evidence for grassland conversion. As previously discussed in the current report and in the NGES report (2022), these references have major flaws including the low confidence of the CDL data they used in differentiating between grassland, pasture, and crop-rotation land classifications as described in our report in Section 4.1. For this reason, we urge the EPA to explicitly acknowledge the deficiencies of Wright et al. (2017) and Lark et al. (2015) in the final RIA, specifically as they pertain to reporting grassland conversion, or that the references be excluded entirely.

[8] Formally known as the Food, Agriculture, Conservation, and Trade Act of 1990 (Public Law 101-624)
[9] Formally known as the Federal Agriculture Improvement and Reform Act of 1996 (Public Law 104-127)

#### 4.2.3 Wildlife

The DRIA introduces the Wildlife section as a discussion of impacts to wildlife that are linked to changes in wetland and other ecosystems but limits the discussion to birds and pollinators with the reasoning that these groups of organisms are the most studied. The focus on these two receptor groups may result in an unjustified perception that a causal relationship between the RFS and negative effects on wildlife has been established and that these two receptor groups are at particular risk. The discussion of potential impacts to wildlife that the DRIA (and Second Triennial Report) present may give the casual reader a false impression that the impacts it describes are attributable to the RFS. We recommend that EPA consider acknowledging the lack of a quantitative relationship between biofuel feedstock grown specifically to meet the RFS and potential impacts to wildlife from corresponding LUC. Specific comments regarding the discussion of birds and pollinators follow.

##### 4.2.3.1 Birds

The DRIA cites Gleason et al. (2011) in support of the assertion that "Conversion of wetlands to row crops is associated with reduced duck habitat and productivity of duck food sources, including aquatic plants and invertebrates." However, this assertion is not supported by the article cited. Gleason et al. (2011) examined the benefits of programs such as CRP and the Wetland Reserve Program in restoring ecosystem services (including waterfowl habitat services) but did not address habitat loss due to agricultural conversion. Moreover, the paper also did not assess or mention the potential role of the RFS in wetland loss and therefore it has no relevance to the discussion of potential impacts of the RFS. In fact, biofuels are mentioned only in the abstract of the paper and only in the context of the importance of USDA conservation programs in view of increasing demands for agricultural products (food and fiber were also mentioned).

The DRIA cites Fletcher et al. (2011), which conducted a meta-analysis of 15 articles reporting on the difference in vertebrate (mostly bird) biodiversity between agricultural lands devoted to crops that can be used for biofuels and other non-agriculture lands. They noted, however, that only two of the papers that were deemed adequate for their study differentiated between corn and soy. More important, Fletcher et al. (2011) did not attempt to apportion such changes spatially or quantitatively to any direct effects of the RFS. In fact, at an even more fundamental level, the authors acknowledged that "We still know remarkably little about the biodiversity associated with current biofuel crops…." We suggest that EPA acknowledge two things in the final RIA when citing this paper: 1) that the authors made no attempt to quantify any biodiversity impacts to extensification due to the RFS, and 2) the specific weaknesses of the study acknowledged by the authors themselves including the poor state of knowledge regarding biodiversity in fields devoted to growing biofuel feedstock.

Additionally, the DRIA cites a study by Evans and Potts (2015; the DRIA cites Evans et al. 2015) in support of the assertion that grassland bird species are among those species at highest risk from LUC driven by biofuels. Although the DRIA presents a good summary of the study, it does not point out some of the weaknesses of the study that are acknowledged by the authors themselves, for example:

- The counterfactual scenario developed "is simplified in that it does not include a number of other important drivers of agricultural commodity prices and LUC, including growing demand from international markets, commodity market speculation, and exchange rate fluctuations."

- The "results suggest that this approach may overestimate the ecological impact of biofuel expansion due to a relatively inelastic cropland acreage supply response to expected market conditions."
- Use of CDL data which has "very poor" classification accuracy for differentiating between grassland, pasture, and hay management required that the authors merge these land classes into a single category.

We recommend that the EPA explicitly include these weaknesses identified by Evans and Potts (2015) into the final RIA when citing the study.

#### 4.2.3.2 Pollinators

The DRIA discusses the importance of pollinators, mainly focusing on bees, and how populations of bees have declined in recent years. The DRIA acknowledges that pollinator decline is due to many causes such as disease, LUC, and pesticide use[10]. However, the DRIA cites articles which do not directly relate population declines resulting from the production of biofuels or to the enactment of the RFS (Godfray et al. 2014; Goulson et al. 2015; Hellerstein et al. 2017; Koh et al. 2016; Lautenbach et al. 2012; Losey and Vaughan 2006).

The articles the DRIA cites regarding LUC suggest that population declines are due to LUC from many causes, but their estimates of LUC are likely overestimated. Two of the authors discussing the effect of LUC on pollinators used CDL data to calculate LUC (Koh et al. 2016; Hellerstein et al. 2017) which we have shown leads to overestimation of LUC. The analysis in another paper the DRIA cites regarding LUC, Lautenbach et al. (2012), was based on a model using a crop layer with 10 by 10-kilometer resolution. Based on previous critiques of the CDL and the necessary satellite-imagery resolution needed for land cover analyses (Copenhaver 2022), this model from Lautenbach et al. (2012) is not refined enough to differentiate between land use types and their estimates of loss of pollinators due to LUC are likely overestimated.

Understanding the actual harm of pesticide use is complicated for certain types of pesticides. In addition, the mass of pesticide applied to corn crops has decreased since the 1980s (Fernandez-Cornejo et al. 2014; USDA ERS 2018a; USDA NASS 2013). The DRIA cites two articles, Godfray et al. (2014) and Goulson et al. (2015), which discussed the harm to pollinators from neonicotinoid pesticide exposure. These papers reported that neonicotinoid pesticide can impact pollinators but also stated that it is not clear how harmful neonicotinoids truly are. More recent studies have still not clarified the strength of the relationship between neonicotinoid pesticides and pollinator populations. For example, the Singla et al. (2021) paper "Influence of neonicotinoids on pollinators: A review" found that the pesticide negatively impacted various behaviors of pollinators (e.g., foraging, pollination, and reproduction) but did not always lead to pollinator mortality. The authors acknowledged there were many limitations and gaps in this area of research that need to be elucidated in future studies. The final RIA should incorporate discussion of Singla et al. (2021) and clarify that any neonicotinoid harm is not well understood and has not been quantified.

[10] DRIA, pp. 250-251 – "A 2016 modeling study suggests that wild bee populations decreased by 23% across the U.S. between 2008 and 2013.437 The causes of these reductions are complex, but include land use change, pesticides, and disease."

Due in part to EPA regulatory efforts, pesticide use has decreased in the US since the 1980s (Fernandez-Cornejo et al. 2014; USDA ERS 2018a). The EPA Office of Pesticide Programs released the "Policy to Mitigate the Acute Risk to Bees from Pesticide Products" (hereafter, the policy) in 2017 and proposed more actions to protect pollinators in 2020 (EPA 2017; 2022d). This 2017 policy was enacted to mitigate acute hazards to bees from pesticide products by regulating application through practical means such as restricting spraying to times when pollinators are least active. The actions to protect pollinators are also known as the "Proposed Interim Decision on Neonicotinoids," which expands on management measures of the policy. The EPA proposes to cancel the spraying of imidacloprid on turf, keep pesticides on the intended target, reduce the amount used on crops associated with potential ecological risks, and restrict when pesticides can be applied to blooming crops to limit exposure to bees (EPA 2017; 2022e). Ramboll and NGES recommend that the EPA review these new policy measures in the final RIA's pollinator discussion to highlight potential future improvements in agricultural practices that may mitigate potential impacts caused by the RFS.

In summary, the DRIA did not cite any specific source which causally tied corn ethanol biofuel production to pollinator population decline, nor are we aware of any. Thus, we recommend that the EPA clarify this section to state that there is no known causal mechanism between the RFS and pollinator declines, that research into this relationship is lacking, and that cited papers about pollinator decline do not relate to the RFS.

### 5. Soil and Water Quality

The DRIA discusses impacts of biofuels feedstock on soil and water quality together due to their close association. The discussion is mostly general in terms of potential impacts of agriculture, but it does cite several studies that are specific to corn and soy. For example, the DRIA identifies the following potential impacts to soil and water from for agriculture: increased erosion from tilling and other land management practices, fertilizer and pesticide runoff from fields to surface water bodies, depletion of soil organic matter, chemical contamination from releases and spills, and increase loading of nutrients and other agrichemicals resulting in adverse water quality conditions, including potential toxicity to aquatic organisms. The DRIA correctly acknowledges that: 1) The role of the RFS in observed impacts to soil and water quality cannot be estimated (p. 267); 2) future impacts relative to 2022 are likely to be small (p. 267); and 3) there are many effective management practices that can act to counterbalance any negative impacts from corn for ethanol (e.g., p. 257). The final RIA should clarify these positions throughout the discussion of potential water quality impacts.

Over the past few decades, widespread adoption of improved agricultural practices has mitigated many of the impacts described in the DRIA . There is strong evidence that the agricultural community, including biofuel feedstock producers, are adopting modern agricultural practices (Vuran et al. 2018). The 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. In its discussion of impacts to soil and proximal water quality (DRIA, p. 255), the DRIA presents a calculation of a theoretical increase in nitrogen applied to farm fields nationwide due to corn extensification, but this calculation is flawed because the assumption regarding acres of extensification for corn is based on the work of Lark et al. (2015) which has been shown to be unreliable. We recommend that EPA remove this example calculation from the text of the final RIA because it is erroneous. Similarly, the DRIA cites Garcia et al. (2017) who estimated that corn production between 2002 and 2022 would result in nitrate groundwater contamination of greater than 5 milligrams per liter in areas with sandy or loamy soils. However, this estimate is based on corn production in general and the authors did not attempt to associate the increased nitrates in groundwater to any effect of the RFS. In the absence of evidence of a quantitative causal relationship, the discussion in the DRIA of the relationship between agriculture (and corn growing in particular) and proximal water quality creates the misleading impression of a direct causal relationship.

Similarly, the DRIA presents a discussion of the potential downstream effects of corn and soy cultivation. In terms of aquatic life, the DRIA discusses the biological condition of the nation's rivers, streams, and lakes and the causative factors contributing to poor conditions. The DRIA cites source documents that mention nutrient enrichment as a leading contributor to degraded water quality conditions nationwide. Throughout these discussions, the DRIA provides no link to biofuels crops or the RFS other than to note that several areas with the worst problems are in areas where biofuels crops are prevalent. Because the DRIA does not acknowledge this lack of nexus to the RFS, it creates the false impression that widespread water quality degradation is due to biofuel crop intensification and extensification that is driven by the RFS. The final RIA should acknowledge that there have been no studies establishing such a quantitative causal link between the RFS and soil and water quality.

As it did in 2021, the DRIA mentions the role of nutrient enrichment in the formation of very large-scale hypoxic events in western Lake Erie or the Gulf of Mexico. However, the DRIA does not discuss what, if any, influence biofuels feedstock production may have in eliciting this phenomenon. Perhaps most important, the DRIA does not mention that regional hypoxic conditions in western Lake Erie and the Gulf of Mexico were increasing in frequency and severity long before ethanol production increased and that nitrogen loading to the Gulf of Mexico remained fairly constant from the early 1990s through about 2008 and then actually began a decreasing trend (Figure 5-1). The DRIA ignores a rich literature describing the complexity of these phenomena and does not explicitly state that the eutrophication studies it cites (e.g., Secchi et al. 2011) did not attempt to estimate increased nutrient input from biofuels crops grown to meet demand from the RFS (this topic is discussed in more detail at Ramboll 2019, pp. 26-27). We recommend that the final RIA include a discussion of the lack of causal evidence linking the RFS to these phenomena.

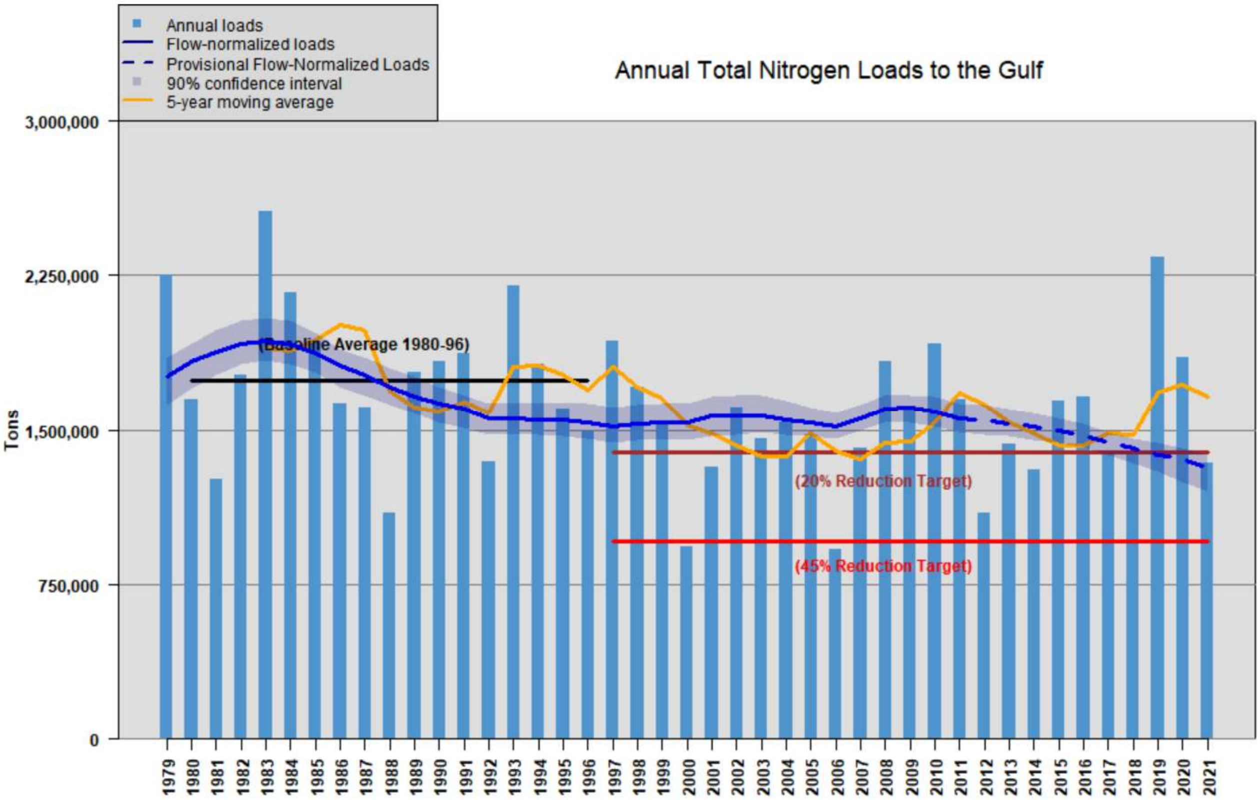



**Figure 5-1. Annual Nitrate and Nitrite Loading to the Gulf of Mexico 1980-2021**

Data Source: US Geological Survey 2021

The DRIA also discusses the potential for deleterious effects on aquatic life from pesticides applied to corn and soybeans and in support of such statements, cites various toxicological studies. Among the papers EPA cites are studies of glyphosate (the active ingredient in Roundup) on fish including sublethal effects such as DNA damage and altered muscle and brain function. For example, a study by Guilherme et al. (2012) reported on observed genetic damage from acute exposure of a single test species (*Anguilla anguilla*, European eel) to glyphosate in water using the comet assay. The comet assay is a sensitive test that is not specific to chemical stressors in general and certainly not specific to agrochemicals such as glyphosate. In addition, the test is fraught with problems of interpretation as well as laboratory practices that can dramatically affect results. For example, Braafladt et al. (2016) described sources of variability in the comet assay that included variations in the protocol used to process the cells, the microscope imaging system used, and the software used in the computerized analysis of the images. The authors stated that "Manual image analysis revealed measurement variations in percent DNA in tail as high as 40% due to microscope focus, camera exposure time and the software image intensity threshold level." McArt et al. (2009) highlighted limitations in the use of the comet assay, including lack of standardization such as solution molarity, pH, the use of protein digests, wash times, unwinding times, and electrophoresis times which can all contribute to differences in the scoring values obtained. In addition, the authors maintained that certain aspects of the comet protocol are open to selection bias associated with investigator choice on the number and location of comets to analyze. In addition to the poor reliability of comet assays, there is no way to interpret the result in terms of potential effects at the organism or population level.

The DRIA also cites toxicological studies using physiological (biomarker) responses. Like comet assays, such studies cannot be extrapolated to individual or population level effects and are not chemical specific, rather the results simply indicate that an organism, organ, or tissue has been exposed to a substance that is known to elicit the measured response (e.g., Modesto and Martinez 2010). We recommend that EPA delete citations to toxicological studies that rely on biomarkers. For example, both EPA and USDA have issued fact sheets acknowledging that glyphosate is practically nontoxic to fish and aquatic invertebrates (EPA 1993; USDA 1997). More recent review articles of the aquatic toxicity of glyphosate agree with these earlier findings (e.g., Bastos et al. 2018 and Solomon and Thompson 2003). The EPA could cite these studies (EPA 1993; USDA 1997; Bastos et al. 2018 and Solomon and Thompson 2003) in the final RIA in place of the biomarker studies.

In summary, the general discussion of soil and water quality impacts from agriculture is missing an adequate discussion of the lack of a causal relationship between the RFS and the impacts discussed. The DRIA also fails to adequately acknowledge the role of ongoing adoption of modern agricultural practices such as precision agriculture in mitigating such impacts (e.g., see for example Ramboll 2019, pp. 31-33).

## 6. Water Quantity and Availability

Like other areas of our review (Economic, Environmental & Ecological, Soil & Water Quality), the DRIA provides the foundation for Ramboll's analysis of the effect of the proposed volumes on water quality and water availability. A key statement presented within the DRIA regarding water quantity and water availability is:

> "To our knowledge, 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." (DRIA, p. 273)

However, current wording in the DRIA suggests that corn, specifically corn for biofuels, is a driver for change in the High Plains Aquifer (HPA) levels. Specifically, the DRIA states "Water intensive corn and soybean production occurs on irrigated acres in states such as Nebraska and Kansas, in particular, the western parts of those states. These states also overlap the High Plains Aquifer (HPA) "where groundwater levels have declined at unsustainable rates. (Smidt et al. 2016)" (DRIA, p. 268) Changing and declining water levels in the HPA are not disputed. However, the EPA cites literature that attempts to connect an alleged increase in corn acreage to changes in HPA water levels such as Smidt et al. (2016), Wu et al. (2014), and Liu et al. (2017).

Ramboll's analysis on water quantity and availability includes reviewing literature the DRIA relies on regarding water quantity impacts and water levels in the HPA (particularly in Nebraska), including the following:

- EPA (2018): Biofuels and the Environment: Second Triennial Report to Congress.
- Wu et al. (2014): Life-cycle water quantity and water quality implications of biofuels.
- Smidt et al. (2016): Complex water management in modern agriculture: Trends in the water-energy-food nexus over the High Plains Aquifer.

- National Academy of Sciences (2011): Renewable Fuel Standard: Potential Economic and Environmental Effects of U.S. Biofuel Policy.
- Dominguez-Faus et al. (2009): The water footprint of biofuels: A drink or drive issue?
- Gerbens-Leenes and Hoekstra (2012): The water footprint of sweeteners and bio-ethanol.
- Liu et al. (2017): Potential water requirements of increased ethanol fuel in the USA.

Ramboll's findings based on a review of this literature are as follows.

- The HPA water levels within the states where most corn is grown, Nebraska and South Dakota, are renewed in a normal precipitation year (McGuire and Strauch 2022).
- HPA levels in Nebraska have remained relatively constant or have increased over time.
- In general, Nebraska corn yields steadily increased in the period from 2005 through 2017 while HPA levels have remained relatively constant. An exception to this general trend is the period from 2011 through 2013 when both corn yields and HPA levels decreased as result of below average annual precipitation.
- Groundwater depletion in the HPA is further south over Oklahoma and Texas where the climate is drier and where only 4% of the ethanol plants in the country exist.
- Technological advances have reduced and are expected continue reducing the amount of water used for corn production.

EPA should address these key points in the final DRIA.

## 6.1 Impact of Corn Production on the HPA

Although there are eight states that exist within the boundaries of the HPA, corn is the most grown crop in only two of them: Nebraska and South Dakota. In those two states, the HPA water levels are renewed in a normal precipitation year (McGuire and Strauch 2022). Figure 6-1 represents the water level changes in the HPA from pre-development to 2017 over the eight states where the HPA is located along with the location and capacity of ethanol plants in the HPA (McGuire and Strauch 2022; National Renewable Energy Laboratory 2023). This figure indicates that most ethanol plants exist within central and eastern Nebraska where HPA level changes are primarily non-existent or the levels have risen. There are areas of southeast Nebraska where water levels declined within the range of 5 to 25 feet. However, as stated in the introduction, there have been no comprehensive studies that attribute decreasing groundwater supplies to the increased production of corn grain-based ethanol and soybean-based biodiesel.

Figure 6-1 further indicates that the location where significant groundwater depletion is occurring in the HPA is further south over Oklahoma and Texas where the climate is typically drier than the northern HPA. It should be noted that only about 4% of the ethanol plants in the country are in this portion of the HPA.

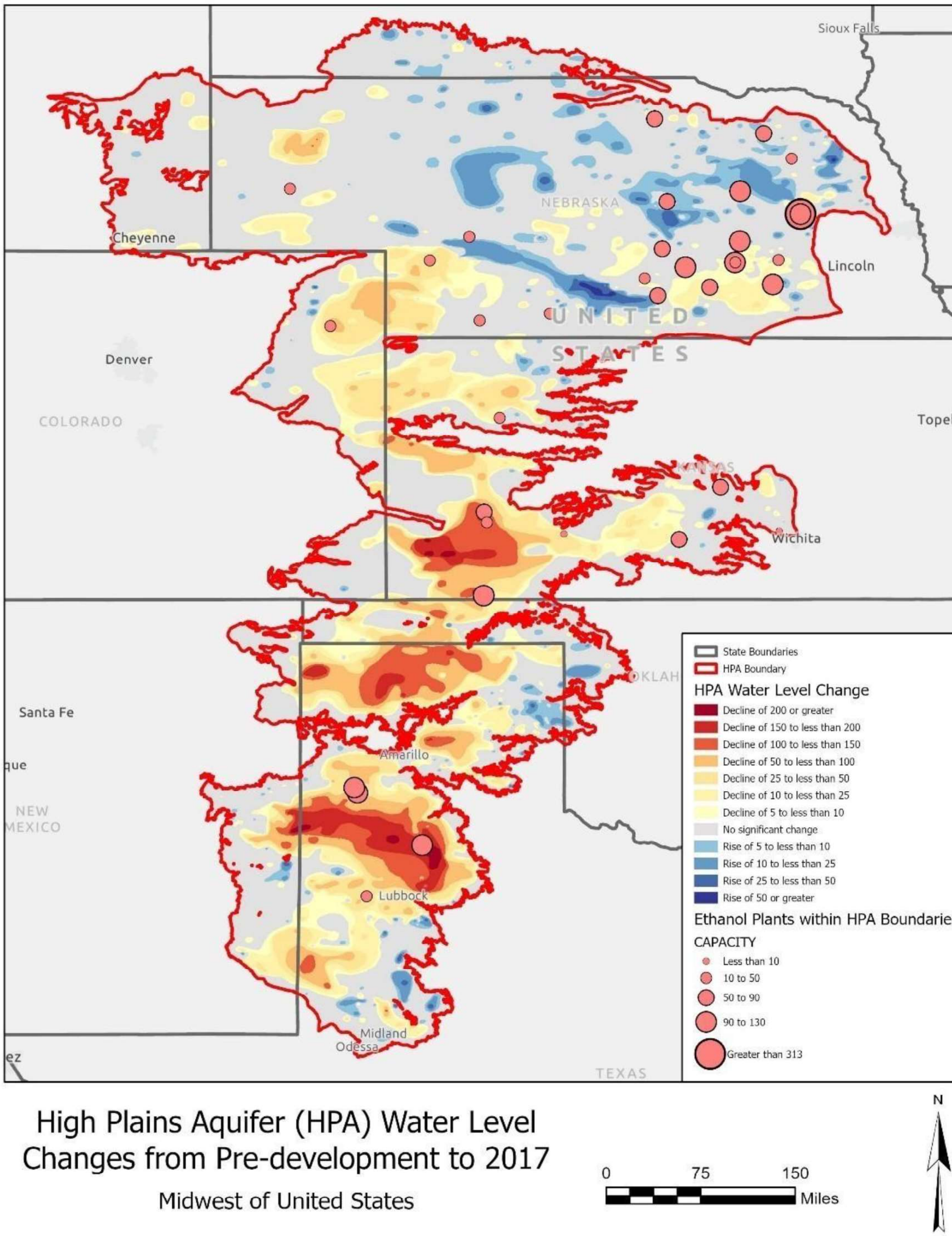



**Figure 6-1. High Plains Aquifer (HPA) Water Level Changes from Pre-Development to 2017 in the Midwest of the US and Ethanol Refinery Locations based on their Capacity**

Sources: McGuire and Strauch (2022); National Renewable Energy Laboratory (2023)

The fact that the largest amount of groundwater depletion in the HPA occurs in Oklahoma and Texas, where the climate is much drier, points to the fact that when considering changes in HPA levels, one must also consider changes in average annual precipitation. Figure 6-2 shows the relationship between the average annual precipitation and HPA levels in Nebraska overlaid by the bushels of corn produced in the state. Inspection of the figure clearly shows that:

- HPA levels have remained relatively constant or have increased over time, as indicated by the green line representing the HPA level remaining relatively flat over time.
- Years of low average annual precipitation correlate with low HPA levels. This is evidenced by the dips in the blue line, which represents precipitation, being followed by dips in the green line, which represents the HPA level. This is most prominent from 2011 to 2013.
- Corn yields have steadily increased while HPA levels have remained relatively constant. This is evidenced by the orange line representing corn yield increasing over time.
- Corn yield decreases in years of low average annual precipitation as evidenced in the years 2011 to 2013. This decrease also demonstrates that corn production in Nebraska is largely dependent on annual precipitation and not withdrawal from the HPA.

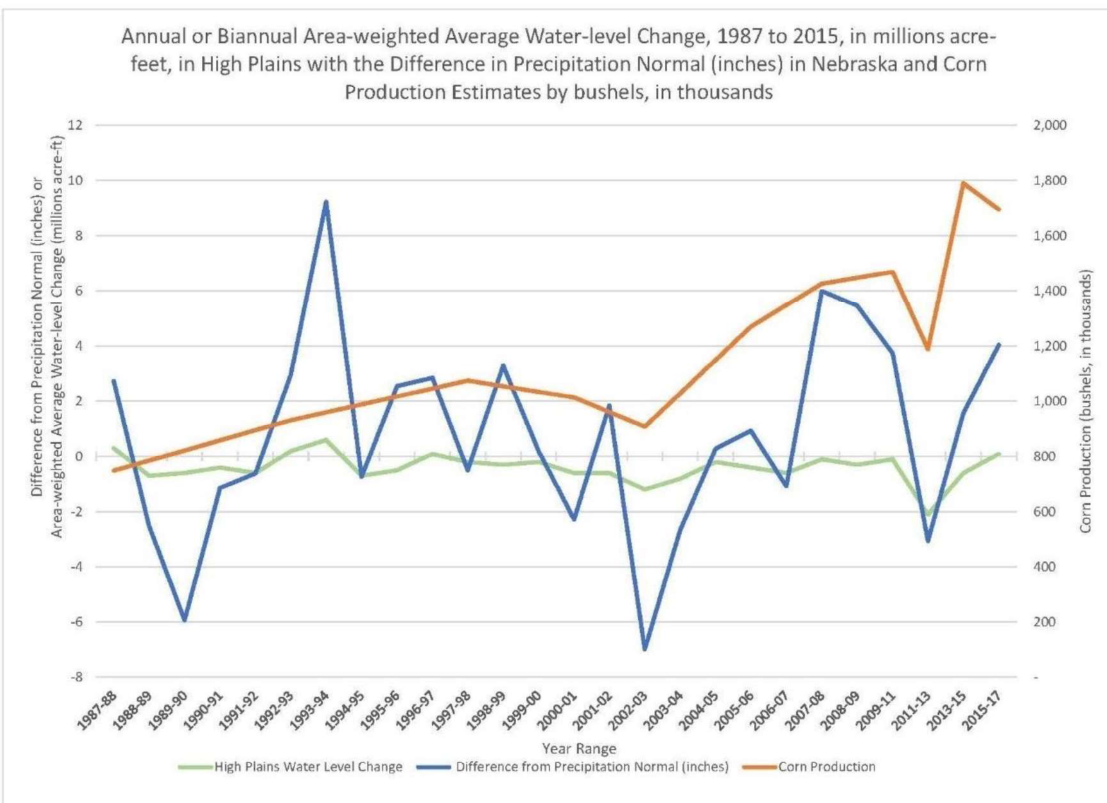



**Figure 6-2. Comparison of Average Annual Precipitation to HPA Levels and Corn Production in Nebraska**
Sources: Nebraska Corn Board 2023; National Oceanic and Atmospheric Administration 2023; US Geological Survey 2023; USDA NASS 2014

## 6.2 Other Factors Affecting the HPA

Although our discussions regarding Figures 6-1 and 6-2 focus on the effects of corn production on the HPA, the corn in these figures is not limited to that which is grown for biofuel. Water removed from the HPA is also used to irrigate corn grown for other purposes such as food for livestock. In addition, there are other uses of water that contribute to decreases in the HPA including livestock production, municipal and industrial use, and growth of other crops. The other major crops harvested in the HPA areas of Nebraska are wheat, soybeans, alfalfa, and sorghum. Nebraska commits large areas of production to other crops including approximate 5.5 million acres to soybeans, 5.1 million acres to hay, 1.6 million acres to wheat for a total of approximately 12.2 million acres. The area for these others crops exceed the 9.9 million acres used for corn (Nebraska Corn Board 2022). The state also supplies ~20% of the nation's cattle (USDA NASS 2023b).

## 6.3 Advanced Agriculture and Reduction in Water Use

The USDA anticipates improvements in corn production practices and techniques to result in a yield increase of 16.1 more bushels per harvested acre by 2028 (USDA NASS 2018); thus, provided that these technological and methodological changes are made, significant reductions in water use will continue to take place for corn production. While the percentage of harvested corn acres has dropped from 80% irrigated in 1979 to 70% irrigated in 2013 (USDA NASS 2013), irrigated corn still disproportionately represents the top source of agriculturally consumed water (USDA-ERS 2022). In 2012, corn production accounted for approximately 25% of total U.S. irrigated acreage harvested (USDA-ERS 2022). With an emphasis on water-related technology and methodological changes in the late 2010s, Table 6-1 provides an overview of a selection of beneficial prevailing opportunities for water savings in irrigated agriculture. A review of literature suggests that upwards of 50% of irrigated water can be eliminated by instituting such pre-established practices (Shangguan et al. 2002).

**Table 6-1. 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 (ROI) can accrue within 2—5 years. In 2007, only 0.1% of irrigated corn farms used this. |
| Rainwater 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. |

| Technological Advancement | Approximate water savings factor | Baseline scenario | Demonstrated potential yield increase | Notes |
|---|---|---|---|---|
| Precision agriculture | **13%** | vs. without government-run weather network | **8%** | Includes use of GPS, GIS, 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. |

Because water supply is a concern irrespective of corn and biofuel production, there is also a precedent for subsidized government programs that successfully implement these new technologies for the benefit of the farmers. For example, because of prolonged drought conditions, California installed a network of 145 automated statewide weather stations, so that farmers could manage their water resources more efficiently (California Irrigation Management Information System 2023).

Generally, opportunities for technology improvement are found when considering irrigation system development. For example, in 2018, fewer than 10% of irrigators used soil- or plant- moisture sensing devices or commercial scheduling services, and fewer than 2% used simulation models that are based on corn growth patterns and weather conditions (USDA ERS 2018b). However, adoption of more efficient technologies is growing in the U.S., especially in the western U.S. where the percent of crops irrigated with more efficient pressurized (versus gravity) irrigation systems had increased to 72% by 2018, compared to 37% in 1984 (USDA ERS 2022).

Barriers to implementation of these measures may include such issues as: 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) insufficient self-funding by the farmers. 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).

While controversial, genetic engineering or selection for improved drought tolerant corn cultivars has also contributed to increases in corn crop productivity as part of ethanol production. Genetic breeding has also 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 et al. 2017).

Altogether, there is still significant potential for increases in yield and decreases in irrigation, which ultimately will address water quality concerns caused by leaching or run-off of chemicals to both the subsurface and to surface water.

## 6.4 Reduction in Water Usage for Ethanol Processing

With the data available, trends suggest an overall decrease in consumptive biofuel production water use over time, due to advances in technology and in the efficiency of existing plants. In 1998, the average dry mill consumed 5.8 gallons of water per gallon of ethanol. However, by 2009, the U.S. Department of Energy estimated this had been reduced to approximately 3 gallons of water per gallon of ethanol. Wu et al. (2018) 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.

## 6.5 Technology Changes and Reduction in Chemical Use

Recent advancement in technology in agriculture practices have increased the crop yield without changes in the water usage. It is not unusual for farmers to adopt such new practices as part of pre-existing agricultural operations. In 2011 and 2012, 78% of total corn acres were planted in rotation with soybean and/or other for-sale crops (Atwell et al. 2016; Azevedo et al. 1999; Barton and Clark 2014; Foodwise 2014). This "conservation tillage" method has been shown to result in an approximately 9.6% increase in yield (Atwell et al. 2016; Azevedo et al. 1999; Barton and Clark 2014; Foodwise 2014).

Based on discussions with Professor M. Ruark of University of Wisconsin, Madison, the application of slow released (or controlled) nitrogen fertilizer during peak uptake is key to improving nutrient efficiency and utilization (Lal and 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).

A similar method called fertigation (alternate partial root-zone drip irrigation) has been shown to improve the nitrogen uptake in addition to water-use-efficiency (WUE) without greater yield loss. Some additional studies have shown that fertigation can generally improve the WUE while reducing the nitrogen leaching in subsurface (Fu et al. 2017).

Ramboll recognize that genetic engineering can be controversial, but it has enabled these benefits which can be used to address potential challenges such as aquatic dead zones. Combined with advanced chemical technologies, including slow-release nitrogen-based fertilizers and bio-inhibitors, additional reductions in pesticide and fertilizer use are possible in corn production. Use of bioreactors, for instance, which involves redirecting water through tiles to underground woodchips where nitrate is removed by microorganisms, can reduce nitrogen pollution in run-off by 15 to 90% (Christianson 2016; Iowa Corn Growers Association 2023).

## 6.6 Recommendations Regarding Factors Influencing HPA Levels

From our literature review, we agree with the EPA that the RFS does not have a known causal connection with impacts to water quantity[11], although there is evidence that water quantities could be affected by additional irrigation[12]. However, our research also indicated that there are other factors that influence groundwater withdrawals from the HPA that we recommend be acknowledged and discussed in the final RIA, including precipitation patterns, drought years, other uses of corn production, and improved technology.

# 7. References


Alternative Fuels Data Center. 2021. U.S. Ethanol Plants, Capacity, and Production. [accessed 2023 Jan 10]. https://afdc.energy.gov/data/10342.

Atwell R, Mirsky S, Moyer J, Poffenbarger H, Reberg-Horton C, Zinati G. 2016. Organic No-Till Corn Production: Cover Crop and Starter Fertilizer Considerations. Rodale Institute. June 2. https://rodaleinstitute.org/science/articles/organic-no-till-corn-production-cover-crop-and-starter-fertilizer-considerations/.

Austin KG, Jones JPH, Clark CM. 2022. A review of domestic land use change attributable to U.S. biofuel policy. Renewable and Sustainable Energy Reviews. 159:Article 112181. doi:10.1016/j.rser.2022.112181.

Azevedo DMP de, Landivar J, Vieira RM, Moseley D. 1999. The effect of cover crop and crop rotation on soil water storage and on sorghum yield. Pesquisa Agropecuária Brasileira. 34:391–398. doi:10.1590/S0100-204X1999000300010.

Barton B, Clark SE. 2014. Water & Climate Risks Facing U.S. Corn Production: How Companies & Investors Can Cultivate Sustainability. Boston, MA: Ceres. June. http://www.ourenergypolicy.org/wp-content/uploads/2014/06/ceres-corn.pdf.

Bastos Gonçalves B, Cardoso Giaquinto P, dos Santos Silva D, Silva Neto CM, Alves de Lima A, Brito Darosci AA, Laço Portinho J, Fernandes Carvalho W, Lopes Rocha T. 2020. Ecotoxicology of glyphosate-based herbicides on aquatic environment. In: Biochemical Toxicology: Heavy Metals and Nanomaterials. IntechOpen. https://doi.org/10.5772/intechopen.85157.

Braafladt S, Reipa V, Atha DH. 2016. The comet assay: Automated imaging methods for improved analysis and reproducibility. Sci Rep. 6(1):32162. doi:10.1038/srep32162.

California Irrigation Management Information System. 2023. CIMIS Overview. [accessed 2023 Feb 1]. https://cimis.water.ca.gov/.

Camp KM. 2019. The relationship between crude oil prices and export prices of major agricultural commodities. Beyond the Numbers US Bureau of Labor Statistics. 8(7). https://stats.bls.gov/opub/btn/volume-8/the-relationship-between-crude-oil-and-export-prices-of-major-agricultural-commodities.htm.


[11] DRIA, p. 273 – "To our knowledge, 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."

[12] DRIA, p. 274 – "While difficult to attribute how much additional water use might be required as a result of the candidate volumes in this rule, there are several lines of evidence that suggest increased production of corn-based ethanol and soybean-based biodiesel will increase water demands and, potentially, affect limited water supplies."

Carter CA, Rausser GC, Smith A. 2011. Commodity booms and busts. Annual Review of Resource Economics. 3(1):87–118. doi:10.1146/annurev.resource.012809.104220.

Carter CA, Rausser GC, Smith A. 2017. Commodity storage and the market effects of biofuel policies. American Journal of Agricultural Economics. 99(4):1027–1055. doi:10.1093/ajae/aaw010.

Centers for Disease Control and Prevention. 2017. Methyl tert-Butyl Ether (MTBE) Factsheet. [accessed 2023 Jan 16]. https://www.cdc.gov/biomonitoring/MTBE_FactSheet.html.

Christianson L. 2016. Reducing Water Pollution with Microbes and Wood Chips. The Conversation. July 5. https://theconversation.com/reducing-water-pollution-with-microbes-and-wood-chips-58852.

Copenhaver KL. 2022. Combining tabular and satellite-based datasets to better understand cropland change. Land. 11(5):714. doi:10.3390/land11050714.

Dominguez-Faus R, Powers SE, Burken JG, Alvarez PJ. 2009. The water footprint of biofuels: A drink or drive issue? Environmental Science & Technology. 43(9):3005–3010. doi:10.1021/es802162x.

Dunn JB, Merz D, Copenhaver KL, Mueller S. 2017. Measured extent of agricultural expansion depends on analysis technique. Biofuels, Bioproducts and Biorefining. 11(2):247–257. doi:10.1002/bbb.1750.

EPA (Environmental Protection Agency. 1993. R.E.D. Facts: Glyphosate. United States Environmental Protection Agency, Prevention, Pesticides and Toxic Substances. Report No.: EPA-738-F-93-011. September.

EPA. 2010. Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis. United States Environmental Protection Agency, Office of Transportation and Air Quality, Assessment and Standards Division. Report No.: EPA-420-R-10-006. February.

EPA. 2017. U.S. Environmental Protection Agency's Policy to Mitigate the Acute Risk to Bees from Pesticide Products. U.S. Environmental Protection Agency, Office of Pesticide Programs. January 12. https://www.regulations.gov/document/EPA-HQ-OPP-2014-0818-0477.

EPA. 2018. Biofuels and the Environment: Second Triennial Report to Congress. Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development. Report No.: EPA/600/R-18/195F. June. https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=IO&dirEntryId=341491.

EPA. 2022a. Renewable Fuel Standard (RFS) Program: Standards for 2023-2025 and other changes. Proposed rule. Federal Register. 87(250):80582–80756.

EPA. 2022b. Draft Regulatory Impact Analysis: RFS Standards for 2023-2025 and Other Changes. United States Environmental Protection Agency, Office of Transportation and Air Quality, Assessment and Standards Division. Report No.: EPA-420-D-22-003. November.

EPA. 2022c. Renewable Fuel Standard Program. [accessed 2023 Jan 13]. https://www.epa.gov/renewable-fuel-standard-program.

EPA. 2022d. EPA Actions to Protect Pollinators. United States Environmental Protection Agency. [accessed 2022 Dec 22]. https://www.epa.gov/pollinator-protection/epa-actions-protect-pollinators.

Evans SG, Potts MD. 2015. Effect of agricultural commodity prices on species abundance of US grassland birds. Environmental and Resource Economics. 62(3):549–565. doi:10.1007/s10640-014-9829-1.

Fernandez-Cornejo J, Nehring RF, Osteen C, Wechsler S, Martin A, Vialou A. 2014. Pesticide Use in U.S. Agriculture: 21 Selected Crops, 1960-2008. Economic Information Bulletin No. 124. United States

Department of Agriculture, Economic Research Service. May. https://www.ers.usda.gov/webdocs/publications/43854/46734_eib124.pdf?v=3178.4.

Fletcher RJ, Robertson BA, Evans J, Doran PJ, Alavalapati JR, Schemske DW. 2011. Biodiversity conservation in the era of biofuels: Risks and opportunities. Frontiers in Ecology and the Environment. 9(3):161–168. doi:10.1890/090091.

Foodwise. 2014. 10 Ways Farmers Are Saving Water. August 15. https://foodwise.org/articles/10-ways-farmers-are-saving-water/.

Fu F, Li F, Kang S. 2017. Alternate partial root-zone drip irrigation improves water – and nitrogen – use efficiencies of sweet-waxy maize with nitrogen fertigation. Sci Rep. 7(1):Article 17256. doi:10.1038/s41598-017-17560-2.

Garcia V, Cooter E, Crooks J, Hinckley B, Murphy M, Xing X. 2017. Examining the impacts of increased corn production on groundwater quality using a coupled modeling system. Science of The Total Environment. 586:16–24. doi:10.1016/j.scitotenv.2017.02.009.

Gerbens-Leenes W, Hoekstra AY. 2012. The water footprint of sweeteners and bio-ethanol. Environment International. 40:202–211. doi:10.1016/j.envint.2011.06.006.

Gleason RA, Euliss Jr. NH, Tangen BA, Laubhan MK, Browne BA. 2011. USDA conservation program and practice effects on wetland ecosystem services in the Prairie Pothole Region. Ecological Applications. 21(Supp 1):S65–S81. doi:10.1890/09-0216.1.

Godfray HCJ, Blacquière T, Field LM, Hails RS, Petrokofsky G, Potts SG, Raine NE, Vanbergen AJ, McLean AR. 2014. A restatement of the natural science evidence base concerning neonicotinoid insecticides and insect pollinators. Proceedings: Biological Sciences. 281(1786):Article 20140558.

Goulson D, Nicholls E, Botías C, Rotheray EL. 2015. Bee declines driven by combined stress from parasites, pesticides, and lack of flowers. Science. 347(6229):Article 1255957. doi:10.1126/science.1255957.

Guilherme S, Gaivão I, Santos MA, Pacheco M. 2012. DNA damage in fish (Anguilla anguilla) exposed to a glyphosate-based herbicide – Elucidation of organ-specificity and the role of oxidative stress. Mutation Research/Genetic Toxicology and Environmental Mutagenesis. 743(1–2):1–9. doi:10.1016/j.mrgentox.2011.10.017.

Hellerstein D, Hitaj C, Smith D, Davis A. 2017. Land Use, Land Cover, and Pollinator Health: A Review and Trend Analysis. Economic Research Report No. 232. United States Department of Agriculture, Economic Research Service. June. https://www.ers.usda.gov/webdocs/publications/84035/err-232.pdf?v=42908.

Index Mundi. 2023. United States Corn Ending Stocks by Year (1000 MT). [accessed 2023 Jan 10]. https://www.indexmundi.com/agriculture/?country=us&commodity=corn&graph=ending-stocks.

Iowa Corn Growers Association. 2023. Conservation Practices. [accessed 2023 Jan 30]. https://www.iowacorn.org/corn-production/environmental/conservation-practices/.

Johnston CA. 2013. Wetland losses due to row crop expansion in the Dakota Prairie Pothole Region. Wetlands. 33(1):175–182. doi:10.1007/s13157-012-0365-x.

Kanaskie LA. 2000. MTBE phaseout: A boon for ethanol producers. Environmental Science and Technology. 34(9):205A-205A. doi:10.1021/es003238w.

Keeney D, Muller M. 2006. Water Use by Ethanol Plants: Potential Challenges. Minneapolis, MN: Institute for Agriculture and Trade Policy.

Koh I, Lonsdorf EV, Williams NM, Brittain C, Isaacs R, Gibbs J, Ricketts TH. 2016. Modeling the status, trends, and impacts of wild bee abundance in the United States. Proceedings of the National Academy of Sciences. 113(1):140–145. doi:10.1073/pnas.1517685113.

Lal R, Stewart BA, editors. 2018. Soil Nitrogen Uses and Environmental Impacts. Boca Raton, FL: CRC Press. https://doi.org/10.1201/b22044.

Lark TJ, Hendricks NP, Smith A, Pates N, Spawn-Lee SA, Bougie M, Booth EG, Kucharik CJ, Gibbs HK. 2022. Environmental outcomes of the US Renewable Fuel Standard. Proceedings of the National Academy of Sciences. 119(9):Article e2101084119. doi:10.1073/pnas.2101084119.

Lark TJ, Salmon JM, Wright CK, Gibbs HK. 2015. Cropland expansion outpaces agricultural and biofuel policies in the United States. Environmental Research Letters. 10(4):Article 44003. doi:10.1088/1748-9326/10/4/044003.

Lark TJ, Schelly IH, Gibbs HK. 2021. Accuracy, bias, and improvements in mapping crops and cropland across the United States using the USDA Cropland Data Layer. Remote Sensing. 13(5):968. doi:10.3390/rs13050968.

Lautenbach S, Seppelt R, Liebscher J, Dormann CF. 2012. Spatial and temporal trends of global pollination benefit. PLoS ONE. 7(4):Article e35954. doi:10.1371/journal.pone.0035954.

Liu X, Hoekman SK, Broch A. 2017. Potential water requirements of increased ethanol fuel in the USA. Energy, Sustainability and Society. 7(1):18. doi:10.1186/s13705-017-0121-4.

Losey JE, Vaughan M. 2006. The economic value of ecological services provided by insects. Bioscience. 56(4):311–323. doi:10.1641/0006-3568(2006)56[311:TEVOES]2.0.CO;2.

Macrotrends. 2022. Corn Prices - 59 Year Historical Chart. [accessed 2022 Dec 22]. https://www.macrotrends.net/2532/corn-prices-historical-chart-data#:~:text=The%20current%20price%20of%20corn,2022%20is%20%246.5350%20per%20bushel.

McArt DG, McKerr G, Howard CV, Saetzler K, Wasson GR. 2009. Modelling the comet assay. Biochemical Society Transactions. 37(4):914–917. doi:10.1042/BST0370914.

McGuire VL, Strauch KR. 2022. Water-Level and Recoverable Water in Storage Changes, High Plains Aquifer, Predevelopment to 2017 and 2015–17. Scientific Investigations Report 2022-5080. United States Department of the Interior, United States Geological Survey. https://doi.org/10.3133/sir20225080.

Modesto KA, Martinez CBR. 2010. Roundup® causes oxidative stress in liver and inhibits acetylcholinesterase in muscle and brain of the fish *Prochilodus lineatus*. Chemosphere. 78(3):294–299. doi:10.1016/j.chemosphere.2009.10.047.

National Academy of Sciences. 2011. Renewable Fuel Standard: Potential Economic and Environmental Effects of U.S. Biofuel Policy. https://nap.nationalacademies.org/resource/13105/Renewable-Fuel-Standard-Final.pdf.

National Oceanic and Atmospheric Administration. 2023. Statewide Time Series. National Centers for Environmental Information. [accessed 2023 Jan 3]. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/statewide/time-series/25/pcp/ann/12/1895-2022?base_prd=true&begbaseyear=1901&endbaseyear=2000.

National Renewable Energy Laboratory. 2023. Biofuels Atlas. Geospatial Data Science Applications and Visualizations. [accessed 2023 Jan 5]. https://maps.nrel.gov/?da=biofuels-atlas.

Nebraska Corn Board. 2022. Using Corn for Food and Fuel - Where Nebraska Corn Goes. [accessed 2023 Jan 5]. https://nebraskacorn.gov/corn-101/corn-uses/.

Nebraska Corn Board. 2023. Growing Nebraska Corn - Past and Present. [accessed 2023 Jan 3]. https://nebraskacorn.gov/corn-101/growing-corn/.

NGES. 2022. 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. Shelton, WA: Net Gain Ecological Services. February 3.

Olson DW, Capehart T. 2019. Dried Distillers Grains (DDGs) Have Emerged as a Key Ethanol Coproduct. Amber Waves. https://www.ers.usda.gov/amber-waves/2019/october/dried-distillers-grains-ddgs-have-emerged-as-a-key-ethanol-coproduct/.

Pritsolas J, Pearson R. 2019. Critical Review of Supporting Literature on Land Use Change in the EPA's Second Triennial Report to Congress. Prepared for Renewable Fuels Association.

Ramboll. 2019. The RFS and Ethanol Production: Lack of Proven Impacts to Land and Water. Prepared for Growth Energy by Ramboll. August 18.

Rose R. 2002. Slow release fertilizers 101. In: National Proceedings: Forest and Conservation Nursery Associations - 1999, 2000, and 2001. Proceedings RMRS-P-24. Ogden, UT: United States Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. 304–308. https://www.fs.usda.gov/rm/pubs/rmrs_p024.pdf.

Secchi S, Gassman PW, Jha M, Kurkalova L, Kling CL. 2011. Potential water quality changes due to corn expansion in the Upper Mississippi River Basin. Ecological Applications. 21(4):1068–1084. doi:10.1890/09-0619.1.

Sexton AN, Emery SM. 2020. Grassland restorations improve pollinator communities: A meta-analysis. Journal of Insect Conservation. 24(4):719–726. doi:10.1007/s10841-020-00247-x.

Shangguan ZP, Shao MA, Lei TW, Fan TL. 2002. Runoff water management technologies for dryland agriculture on the Loess. International Journal of Sustainable Development & World Ecology. 9(4):341–350. doi:10.1080/13504500209470129.

Shrestha DS, Staab BD, Duffield JA. 2019. Biofuel impact on food prices index and land use change. Biomass and Bioenergy. 124:43–53. doi:10.1016/j.biombioe.2019.03.003.

Singla A, Barmota H, Kumar Sahoo S, Kaur Kang B. 2021. Influence of neonicotinoids on pollinators: A review. Journal of Apicultural Research. 60(1):19–32. doi:10.1080/00218839.2020.1825044.

Smidt SJ, Haacker EMK, Kendall AD, Deines JM, Pei L, Cotterman KA, Li H, Liu X, Basso B, Hyndman DW. 2016. Complex water management in modern agriculture: Trends in the water-energy-food nexus over the High Plains Aquifer. Science of The Total Environment. 566–567:988–1001. doi:10.1016/j.scitotenv.2016.05.127.

Taheripour F, Baumes H, Tyner WE. 2022a. Economic impacts of the U.S. Renewable Fuel Standard: An ex-post evaluation. Frontiers in Energy Research. 10:Article 749738. doi:10.3389/fenrg.2022.749738.

Taheripour F, Mueller S, Kwon H, Khanna M, Emery I, Copenhaver K, Wang M. 2022b. Comments on "Environmental Outcomes of the U.S. Renewable Fuel Standard." March. https://erc.uic.edu/wp-content/uploads/sites/633/2022/03/Comments-on-Paper-on-Environmental-Outcomes-of-the-U.S.-Renewable-Fuel-Standard-final.pdf.

Taheripour F, Mueller S, Kwon H, Khanna M, Emery I, Copenhaver K, Wang M. 2022c. Response to Comments from Lark et al. Regarding Taheripour et al. March 2022 Comments on Lark et al. Original PNAS Paper. May. https://growthenergy.org/wp-content/uploads/2022/05/Response-to-Lark-et-al_b-May-2022.pdf.

US Energy Information Administration. 2017. Nebraska: State Profile and Energy Estimates. February 16. [accessed 2023 Jan 13]. https://www.eia.gov/state/analysis.php?sid=NE.

US Energy Information Administration. 2023. Petroleum and Other Liquids: Spot Prices. [accessed 2023 Jan 31]. https://www.eia.gov/dnav/pet/pet_pri_spt_s1_a.htm.

US Fish and Wildlife Service. 2023. National Wetlands Inventory: Frequently Asked Questions. United States Fish and Wildlife Service. [accessed 2023 Jan 12]. https://www.fws.gov/page/national-wetlands-inventory-frequently-asked-questions.

US Geological Survey. 2021. Trends in Annual Water-Quality Loads to the Gulf of Mexico. [accessed 2023 Jan 12]. https://nrtwq.usgs.gov/nwqn/#/GULF.

US Geological Survey. 2023. High Plains Water-Level Monitoring Study. Summary Statistics from Past USGS Reports 1987 to 2015. [accessed 2023 Jan 3]. https://ne.water.usgs.gov/projects/HPA/wlc3.html.

US Government Printing Office. 2004. Hearing before the Subcommittee on Clean Air, Climate Change, and Nuclear Safety of the Committee on Environment and Public Works, United States Senate, One Hundred Eighth Congress, First Session on Provisions of the Clean Air Act to Support Clean-Burning Fuel Alternatives, March 20, 2003. Senate Hearing 108-300.

USDA (United States Department of Agriculture). 1997. Glyphosate: Herbicide Information Profile. United States Department of Agriculture, Forest Service, Pacific Northwest Region. February. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev2_025810.pdf.

USDA. 2022. Technical Memorandum: Review of Recent PNAS Publication on GHG Impacts of Corn Ethanol. United States Department of Agriculture, Office of the Chief Economist, Office of Energy and Environmental Policy. December 14. https://www.usda.gov/sites/default/files/documents/USDA-OCE-Review-of-Lark-2022-For-Submission.pdf.

USDA ERS (Economic Research Service). 2018a. Fertilizer Use and Price. United States Department of Agriculture, Economic Research Service.

USDA ERS. 2018b. Irrigation & Water Use. United States Department of Agriculture, Economic Research Service. [accessed 2018 Feb 1]. https://www.ers.usda.gov/topics/farm-practices-management/irrigation-water-use/#crops.

USDA ERS. 2022. Farming and Farm Income. United States Department of Agriculture, Economic Research Service. [accessed 2022 Dec 22]. https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/farming-and-farm-income/.

USDA NASS (National Agricultural Statistics Service). 2013. Farm and Ranch Irrigation Survey. United States Department of Agriculture, National Agricultural Statistics Service.

https://www.nass.usda.gov/Publications/AgCensus/2012/Online_Resources/Farm_and_Ranch_Irrigation_Survey/.

USDA NASS. 2014. 2012 Census of Agriculture. Nebraska State and County Data. Volume 1, Geographic Area Series, Part 27. AC-12-A-27. May. https://agcensus.library.cornell.edu/wp-content/uploads/2012-Nebraska-nev1-1.pdf.

USDA NASS. 2018. QuickStats [Search Query]. United States Department of Agriculture, National Agricultural Statistics Service. [accessed 2018 Feb 1]. https://quickstats.nass.usda.gov/#09FECD51-EE42-3385-B86A-0CD59F0841A0.

USDA NASS. 2023a. Statistics by subject. United States Department of Agriculture, National Agricultural Statistics Service. [accessed 2023 Jan 5]. https://www.nass.usda.gov/Statistics_by_Subject/index.php?sector=CROPS.

USDA NASS. 2023b. 2021 State Agriculture Overview: Nebraska. United States Department of Agriculture, National Agricultural Statistics Service. [accessed 2023 Jan 5]. https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=NEBRASKA.

Verbeek M. 2017. Using linear regression to establish empirical relationships. IZA World of Labor, Article 336. doi:10.15185/izawol.336.

Vuran MC, Salam A, Wong R, Irmak S. 2018. Internet of underground things: Sensing and communications on the field for precision agriculture. In: 2018 IEEE 4th World Forum on Internet of Things (WF-IoT). p. 586–591. https://doi.org/10.1109/WF-IoT.2018.8355096.

Wadhwa M, Bakshi MPS. 2016. Application of waste-derived proteins in the animal feed industry (Chapter 10). In: Dhillon GS, editor. Protein Byproducts: Transformation from Environmental Burden into Value-Added Products. Elsevier. p. 161–192. https://doi.org/10.1016/B978-0-12-802391-4.00010-0.

Wright CK, Larson B, Lark TJ, Salmon JM, Gibbs HK. 2017. Recent grassland losses are concentrated around U.S. ethanol refineries. Environmental Research Letters. 12:Article 044001.

Wright CK, Wimberly MC. 2013. Recent land use change in the Western Corn Belt threatens grasslands and wetlands. Proceedings of the National Academy of Sciences. 110(10):4134–4139. doi:10.1073/pnas.1215404110.

Wu M, Mintz M, Wang M, Arora S, Chiu Y-W, Xu H. 2018. Consumptive Water Use in the Production of Ethanol and Petroleum Gasoline—2018 Update. Lemont, IL: Argonne National Laboratory. Report No.: ANL/ESD-09/01 Rev. 2. https://publications.anl.gov/anlpubs/2019/01/148043.pdf.

Wu M, Zhang Z, Chiu Y. 2014. Life-cycle water quantity and water quality implications of biofuels. Current Sustainable/Renewable Energy Reports. 1(1):3–10. doi:10.1007/s40518-013-0001-2.

Xue Q, Marek TH, Xu W, Bell J. 2017. Irrigated corn production and management in the Texas High Plains. Journal of Contemporary Water Research & Education. 162(1):31–41. doi:10.1111/j.1936-704X.2017.03258.x.

**Growth Energy Comments on "Biofuels and the Environment: Third Triennial Report to Congress (External Review Draft)"**

Docket ID No. EPA–HQ–ORD–2020–0682

# Exhibit 3

**Comments on Chapter 8 of the**
**"Biofuels and the Environment: Third Triennial Report to Congress (External Review Draft)"**

Air Improvement Resource, Inc.
March 6, 2023

## 1. Introduction

EPA released an external review draft of its Third Triennial Report to Congress (3RtC) on biofuels on January 3, 2023.[1] Chapter 8 of this report summarized EPA's assessment of Air Quality impacts of biofuels (both ethanol and biodiesel). Overall, EPA concluded that there "is no new evidence that contradicts the fundamental conclusions of previous biofuels Reports to Congress." [2]

We have several major comments on this chapter. First, in its discussion of end-use emissions of corn ethanol, EPA failed to review the California E15 study of 20 LEV3 vehicles that showed that higher ethanol-content fuel blends significantly reduced PM emissions. The finding contradicts prior research that EPA relies on in the Triennial Report. Second, EPA relies on ozone air quality analyses it conducted as part of its Anti-Backsliding Study to show a small increase in ozone due to the RFS. But this ozone modeling used fuel properties for conventional gasoline areas that severely underestimated the impact of ethanol on other fuel properties such as aromatics, T50, and T90. Aromatics, T50, and T90 values are significant contributors to exhaust PM, VOC, and NOx emissions. Ethanol has lowered aromatics, T50, and T90 levels, so it is critical to properly account for ethanol's effect on aromatics and other fuel properties when evaluating the air quality impacts of ethanol consumption. Even with EPA's faulty fuel property data, the ozone increase on average was only 0.36%. EPA should either repeat this ozone modeling using the correct fuel data, or simply conclude that there is no effect of corn ethanol on average ozone in the U.S.

This report provides AIR's comments on EPA's findings in Chapter 8 of the report relative to corn ethanol. This document is organized as follows:

- Brief summary of EPA's conclusions
- AIR's comments

## 2. Brief Summary of EPA's Analysis in Chapter 8

EPA's findings are summarized below[3]:

---

[1] *Biofuels and the Environment Third Triennial Report to Congress External Review Draft (ERD*),
U.S. Environmental Protection Agency Office of Research and Development Washington, DC EPA/600/R-22/273.
[2] Page 8-2 of Reference 1
[3] Page 8-2 and 8-3 of Reference 1

- Increased corn production results in higher agricultural dust and $NH_3$ emissions from fertilizer use. Increased corn ethanol production and combustion leads to increased NOx, VOCs, $PM_{2.5}$, and CO.
- EPA's anti backsliding study examined the impacts of air quality from end-use changes in vehicle and engine emissions resulting from required renewable fuel volumes under the RFS. Compared to the 2016 "pre-RFS" scenario, a 2016 with RFS scenario increased concentrations of ozone across the eastern United States, $PM_{2.5}$ concentrations were relatively unchanged in most areas, while $NO_2$ concentrations increased in many areas and CO decreased.
- Using the GREET model, lifecycle emissions from corn ethanol are generally higher than from gasoline for VOCs, SOx, $PM_{2.5}$, $PM_{10}$, and NOx. However, the location of emissions from biofuel production tends to be in more rural areas where there are fewer people.
- On a per unit of energy basis over the period analyzed, biofuels manufacturing has a larger impact than its petroleum counterparts on smog formation, acidification, $PM_{2.5}$ exposure, and ozone depletion potentials, but a smaller potential effect in the total US context due to the smaller size of the biofuels industry. The observed trends seem to indicate that the biofuel industry is consistently reducing emissions as it matures.

## 3. AIR's Comments

### 3.1 End-use emissions

EPA references the CRC E-94-2 and E-94-3 studies as relevant to the impacts of ethanol on emissions from vehicles.[4] The 94-2 study used match blended fuels to evaluate the impacts of ethanol and particulate matter index (PMI) on PM emissions. The 94-3 study examined the effects of splash-blended ethanol fuels on emissions using a subset of vehicles from the 94-2 study. EPA also references two additional studies on the datasets from the EPAct Phase 3 study by Butler and Sobotowski. [5] EPA's conclusions are that "recent research on GDI vehicles has not shown an impact on hydrocarbon and NOx emissions with increasing ethanol levels. However, $PM_{2.5}$ is impacted by ethanol level, and to a greater extent, by PMI." [6]

One additional recent study not referenced by EPA is relevant to end-use emissions, and directly undercuts EPA's conclusions drawn from the older studies discussed above.

---

[4] CRC Report E-94-2, *Evaluation and Investigation of Fuel Effects on Gaseous and Particulate Emissions in SIDI In-Use Vehicles,* Southwest Research Inc. for Coordinating Research Council, March 2017, and CRC Report E-94-3, *Impacts of Splash Blending on Particulate* Emissions from SIDI Engines, Southwest Research Institute for Coordinating Research Council, June 2018.

[5] Butler, A; Sobotowski, R; Hoffman, G; Machiele, P. (2015). Influence of fuel PM index and ethanol content on particulate emissions from light-duty gasoline vehicles. SAE Technical Papers 2015. https://dx.doi.org/10.4271/2015-01-1072, and Sobotowski, R; Butler, A; Guerra, Z. (2015). A pilot study of fuel impacts on PM emissions from light-duty gasoline vehicles. SAE Int J Fuels Lubr 8: 214-233. https://dx.doi.org/10.4271/2015-01-9071.

[6] Page 8-16, lines 383-385, Reference 1.

California/Growth Energy/RFA E15 Study – The University of California Riverside (UCR) tested 20 vehicles with varying technology on E10 and splash-blended E15. This study was conducted for the California Resources Board, Growth Energy, the Renewable Fuels Association, and USCar.[7] Fuels tested were a California RFG E10 and a splash blended E15 made from California RFG E10, using the Federal Test Procedure, or FTP. The study was conducted to determine if the addition of 5% more ethanol in California would increase criteria pollutant or toxic emissions. The E15 was splash blended from E10 due to the expectation that splash blending would be the process fuel suppliers would use to provide E15 in California.

The following statements are excerpts from the executive summary of the report:

- Cold-start and weighted **THC emissions showed statistically significant reductions** of 6% and 5%, respectively, for E15 compared to E10. For the **cold-start NMHC emissions**, E15 showed a 7% **statistically significant reduction** compared to E10, while for the hot-start NMHC emissions, E15 showed a 15% marginally statistically significant reduction compared to E10. The weighted NMHC emissions showed a marginally statistically significant reduction of 8% for E15 compared E10.

- **Cold-start and hot-start CO emissions showed statistically significant reductions** of 12% and 27%, respectively, for E15 compared to E10. The weighted CO emissions showed a statistically significant reduction of 17% for E15 compared to E10 across the fleet of 20 vehicles.

- The **NOx emission differences were not statistically significant** between the two fuels.

- The PM mass showed strong, statistically significant fuel trends over the entire FTP cycle and each individual phase. For the cold-start and hot-running phases, **PM mass emissions showed statistically significant reductions of 17% and 54%**, respectively, for E15 compared to E10. **Hot-start PM mass emissions were 43% lower for E15 compared to E10**, at a marginally statistically significant level. The weighted PM mass emissions showed a statistically significant reduction of 18% for E15 compared to E10 across the fleet of 20 vehicles.

- Only the weighted solid **particle number emissions** were included in the statistical analyses. Results showed that **E15 was 12% lower than E10**, at a statistically significant level.

- For the BTEX and 1,3-butadiene emissions, only ethylbenzene, m/p-xylenes and o-xylene emissions showed statistically significant results between the fuels. For **ethylbenzene**

[7] Karavalakis, Durbin, and Tang, *Final Report*, *Comparison of Exhaust Emissions Between E10 CaRFG and Splash Blended E15,* Prepared for: California Air Resources Board (CARB), Growth Energy Inc./Renewable Fuels Association (RFA), and USCAR, January 2022.

**emissions, E15 showed a statistically significant reduction of 11% compared to E10**. For m/p-xylenes and o-xylene emissions, E15 showed marginally statistically significant reductions of 10% and 9%, respectively, compared to E10.

- Calculated NMOG and ozone forming potential (OFP) emissions data were not included in the comprehensive statistical analysis but were examined for fuel effects using a two-sample equal variance t-test. Both NMOG emissions and OFP showed statistically significant fuel effects for some vehicles, but not for others. Overall, **NMOG emissions trended lower for E15 compared to E10**. Like NMOG, OFP showed a decreasing trend for E15 compared to E10, indicating that the introduction of E15 in the California gasoline market will likely not contribute to increases in ozone formation.

**The E15 study indicates that fuels with ethanol content higher than E10 lower hydrocarbons, CO, NOx, *and* PM.** EPA should take this study into account and update its analysis and conclusions in the Final Triennial Report.

### 3.2 Anti-backsliding study

EPA conducted air quality analyses of the RFS for the 2016 calendar year. Compared to the pre-RFS scenario, EPA's with-RFS scenario:

- Increased ozone across the eastern US, and in some areas of western US
- Concentrations of $PM_{2.5}$ were relatively unchanged
- Increased $NO_2$ across the eastern US and in some areas of western US
- Decreased CO
- Increased acetaldehyde and formaldehyde
- Decreased benzene

AIR submitted comments on EPA's anti-backsliding analysis in 2020, which we are including here as Attachment A, refuting several of these conclusions.[8] We found that the increase in ozone for the with RFS case in the US was extremely small, or about 0.36% (anything below 0.5% could be considered zero). Furthermore, we identified serious problems with EPA's modeling of areas with conventional gasoline (CG). EPA's assumptions for fuel properties in conventional gasoline areas for the with-RFS case did not comport with its own Fuel Trends data.[9] We found that EPA's air quality analysis estimated much higher increases in VOC and NOx (6% and 6.6%, respectively), than if actual fuel properties for conventional areas were used (3.1% increase for VOC, 1.3% for NOx). Thus, the anti-backsliding air quality analyses conducted by EPA is not scientifically reliable and should not be used to conclude that ethanol leads to a

[8] *Review of EPA's Anti-Backsliding Analysis,* AIR, Inc., July 2, 2020 (Attachment A).

[9] The EPA Fuel Trends data and report showed a greater ethanol effect at reducing aromatics, T50, and T90 levels for conventional gasoline (CG) areas than EPA assumed in ozone modeling in its Anti-Backsliding analysis. For example, in its Anti-Backsliding analysis, EPA estimated that ethanol reduced aromatics by only 2.02%, but in its Fuel Trends report it estimates a 6.5% reduction in aromatics. See Table 4 in Attachment A.

small ozone increase. EPA should either redo the anti-backsliding air quality analyses or conclude that ethanol does not lead to even a small ozone increase.

# Attachment A

Supplementing AIR, Inc. Comments on Chapter 8 of the "Biofuels and the Environment: Third Triennial Report to Congress (External Review Draft)"

Containing AIR, Inc. Review of EPA's Anti-backsliding Analysis (July 7, 2020) and all appendixes

**Review of EPA's Anti-backsliding Analysis**

AIR, Inc.

July 7, 2020

## Introduction

EPA released its Anti-backsliding Study for Renewable Fuels in May 2020.[1] Along with the study, EPA released other supporting materials, including a Proposed Determination document.[2] Upon performing an air quality analysis of the impact of the increase in renewable fuels associated with the RFS, and comparing these emission and air quality changes to the effects of the on-road Tier 3 final rule, EPA concluded that fuel regulations to mitigate any emission increases as a result of the Renewable Fuel Standard (RFS) are not necessary.

We agree with EPA that fuel regulations to mitigate such impacts are not necessary. In fact, due to various methodological issues with the fuel properties EPA used, the study overstates any potential negative air quality effects of the RFS. Specifically, the study overstates ozone and PM impacts, and undercounts the reductions of toxics. When using appropriate fuel properties, hydrocarbon and NOx increases are significantly smaller (leading to lower ozone impacts), PM emissions decline instead of increasing (leading to possible PM air quality benefit for the RFS), and toxics benefits of the RFS are higher.

This document is a review of EPA's emission inventory and air quality analysis performed for the Anti-backsliding Study, which appropriately focused on vehicle emissions pursuant to the Clean Air Act's statutory mandate in section 211(v). The document is organized as follows:

- Brief Summary of EPA's Analysis
- AIR's Comments on EPA's Analysis
- Implications

## 1. Brief Summary of EPA's Analysis

EPA evaluated two emissions and air quality scenarios, a "with RFS" scenario and a "no RFS" scenario. EPA evaluated both scenarios for calendar year 2016. The "with RFS" scenario used actual biofuel volumes used in vehicles in 2016. The "no RFS" scenario approximated biofuel volumes from calendar year 2005. Emission inventories were evaluated for calendar year 2016 only in conventional gasoline (CG) areas of the U.S., since all RFG areas already had E10 (10% ethanol by volume) in 2005.

[1] *Clean Air Act Section 211(v)(1) Anti-backsliding Study*, EPA-420-R-20-008, May 2020.

[2] *Proposed Determination for Renewable Fuels and Air Quality Pursuant to Clean Air Act Section 211(v),* EPA-420-D-20-003, May 2020.

Onroad and nonroad emission inventories for the two scenarios were estimated with EPA's MOVES2014 model. EPA did not evaluate potential changes in upstream emissions (transportation and distribution, and refinery and ethanol plant emissions). All conventional gasoline counties have E10 fuel properties for 2016 in MOVES. To evaluate E0 in 2016 (the "No RFS" scenario), EPA made assumptions regarding the properties of a hypothetical E0 used in 2016 based on information from its report on MOVES fuel supply characteristics.[3] In other words, because all areas of the country had E10 in 2016, there was little or no real-world fuel data to evaluate E0 fuel properties on in 2016; thus, E0 fuel parameters in 2016 must be estimated. In particular, EPA used a table from the Fuel Supply Defaults report that illustrates the changes in fuel properties with a change in ethanol. This table is shown as Table 1 below.

**Table 1. MOVES Fuel Adjustment Factors for E0 to E10**

| Fuel | Description | RVP (psi) | Aromatics (vol %) | Olefins (vol %) | E200 (%) | E300 (%) | T50 (F) | T90 (F) |
|---|---|---|---|---|---|---|---|---|
| E10 S | Summer E10 | 1.00 | -2.02 | -0.46 | 3.11 | 0.39 | -6.34 | -1.77 |
| E10 W | Winter E10 | 1.00 | -3.65 | -2.07 | 4.88 | 0.54 | -9.96 | -2.45 |
| E15 S | Summer E15 | | -3.36 | -1.64 | 9.24 | 0.91 | -18.86 | -4.14 |
| E15 W | Winter E15 | | -5.69 | -3.27 | 11.11 | 1.01 | -22.67 | -4.59 |

The table shows that when moving from E0 to E10, RVP increases by 1 psi, aromatics are 2.02% lower, olefins are 0.46% lower, E200 increases by 3.11%, and E300 increases by 0.39%. T50 and T90 are closely related to E200 and E300. These relationships were developed by EPA from analysis of refinery batch data for the nation (not just conventional gasoline areas) reported from the fuel producers for calendar years 2007, 2009 and 2011. The data contain confidential business information from the refiners, and EPA has never described in detail how this analysis was performed. The fuel parameter relationships, particularly the relationship between ethanol increase, and the change in aromatics and T50, are a critical input to EPA's emission inventory analysis for onroad vehicles, and therefore are a critical input to the Anti-backsliding air quality analysis.

EPA's Modeled Results of the "with RFS" Scenario compared to "No RFS":

- <u>Ozone</u>: a modest ozone (8-hour maximum average ozone) increase across the eastern U.S. and some areas of the western U.S., with some decreases in localized areas[4]
- <u>PM</u>: Relatively unchanged in most areas, with increases in some areas, and decreases in some localized areas.[5]

[3] *Fuel Supply Defaults: Regional Fuels and the Fuel Wizard in MOVES2014b,* EPA-420-R-18-008 July 2018.

[4] *Anti-backsliding Study*, Page 6.

[5] *Anti-backsliding Study,* Page 6.

- CO: Decreased concentrations across the U.S., and in some areas of the west, with larger decreases in some areas.[6]
- $NO_2$: Increases across the eastern U.S., and in some areas of the eastern U.S., with larger increases in some urban areas. [7]
- Toxics: Increased concentrations of acetaldehyde and formaldehyde, decreased concentrations of benzene and 1,3 butadiene, and mixed results for acrolein and napthalene.

## 2. AIR's Comments on EPA's Analysis

As an initial matter, EPA's modeled air quality results must be placed in context. The U.S. county average results for 2016 are shown in Table 2.

| Table 2. EPA Estimated County Average Air Quality Impacts of E10 vs E0 | |
|---|---|
| Pollutant | Average % Change |
| Acetaldehyde | 0.4 |
| Acrolein | -0.37 |
| Benzene | -2.64 |
| 1,3 Butadiene | -3.07 |
| CO | -1.29 |
| Formaldehyde | 0.26 |
| Naphthalene | -0.20 |
| $NO_2$[8] | 1.28 |
| Ozone | 0.36 |
| PM2.5 | -0.01 |

EPA's modeling shows an estimated ozone increase is 0.36%. This is very small and could be considered negligible. Of the toxics, acetaldehyde and formaldehyde very slightly increase, but benzene, 1,3 butadiene, and acrolein, and naphthalene are lower. According to the California Air Resources Board's Predictive Model, 1,3 butadiene and benzene are more potent air toxics than formaldehyde and acetaldehyde, thus, their reductions are more significant than the small increases in formaldehyde and acetaldehyde. [9]

Overall, we have two major concerns with EPA's analysis:

---

[6] *Anti-backsliding Study,* Page 6.

[7] *Anti-backsliding Study,* Page 6.

[8] There are no nonattainment areas in the U.S. for NO2. See https://www3.epa.gov/airquality/greenbook/ancl.html

[9] California Procedures for Evaluating Alternative Specifications for Phase 3 Reformulated Gasoline Using the California Predictive Model, Last Amended: August 24, 2012, https://ww2.arb.ca.gov/resources/documents/gasoline-predictive-models-and-procedures. The potency weighting factors for toxics from this source are 1,3 butadiene: 1.0, benzene: 0.17, formaldehyde: 0.035, and acetaldehyde: 0.016. The source does not list potency weighting factors for acrolein or naphthalene.

- Fuel properties used in the MOVES model for the "no RFS" (E0) scenario in 2016
- Fuel correction factors used in MOVES model

These concerns are described below.

### a. *Effects of Ethanol on Fuel Properties in Conventional Gasoline Areas*

EPA's Anti-backsliding analysis used modeled fuel properties, rather than its real-world fuels data. The modeled properties have a tendency to exaggerate ozone and PM impacts and underestimate toxic reductions. As indicated in Table 1, EPA's analysis of fuel properties from refiners for the U.S. indicates that a 10% increase in ethanol reduces aromatics by only 2% and T50 by 6.3F. This is not consistent with data over the 2006-2016 period in EPA's Fuel Trends Report.

As noted above, to perform the Anti-backsliding analysis, one must have fuel properties for E10 and E0 in 2016. EPA attempted to predict from a fuel modeling analysis what the E0 properties would be in 2016 for E0. An alternative method to discerning the fuel properties of a hypothetical E0 in 2016 is to examine how fuel properties changed between 2006 (when there was plenty of E0) and 2016. As described below, this method reveals that certain fuel properties in EPA's method are unrealistic, and thus distort the air quality results of transitioning from E0 to E10 in the "with RFS" scenario.

Specifically, Table 3 shows fuel properties from EPA's Fuel Trends report for conventional gasoline areas for calendar years 2006 and 2016 – the same areas modeled in the Anti-backsliding Study.[10] Ethanol increased from 0.5% to 9.9% between 2006 and 2016. Aromatics declined by 6.5%. T50 declined by 16.3F and T90 by 13.6F.

**Table 3. Fuel Property Trends Between 2006 and 2016 in Conventional Gasoline Areas**

| | Ethanol (vol %) | Aromatics (vol %) | Olefins (vol %) | E200 (%) | E300 (%) | T50 (F) | T90 (F) | RVP (psi) |
|---|---|---|---|---|---|---|---|---|
| 2006 | 0.5 | 28.5 | 11 | 45 | 82 | 210.0 | 334.0 | 8.4 |
| 2016 | 9.9 | 22 | 9 | 53 | 85 | 193.7 | 320.3 | 9.3 |
| Difference (2016-2006) | 9.4 | -6.5 | -2 | 8 | 3 | -16.3 | -13.6 | 0.9 |

Regarding the aromatics decline, EPA's Fuel Trends report made the following two statements:

[10] *Fuel Trends Report: Gasoline 2006-2016,* U.S. EPA, EPA-420-R-17-005., 2017. The earliest years in the Fuel Trends Report is 2006, so in evaluating fuel properties between 2006 and 2016, we are ignoring potential changes between 2005 and 2006, which we understand to be inconsequential.

- "Ethanol's high octane value has also allowed refiners to significantly reduce the aromatic content of the gasoline, a trend borne out by the data."[11]
- "Aromatics levels in the CG gasoline continued to track lower as ethanol has entered the gasoline pool."[12]

Thus, the Fuels Trends report indicates that ethanol was the major contributor to lower aromatics and T50 levels in conventional gasoline areas. Yet EPA's Anti-backsliding Study used its modeled analysis of refinery batch data on all fuels – conventional and RFG – to determine the impact of ethanol on aromatics. This resulted in aromatics and other fuel parameter changes for its hypothetical E0 in 2016 that were much too low for conventional gasoline areas.

If the refinery batch data were publicly available, we would perform an analysis similar to EPA's just for the conventional areas that are being modeled in the Anti-backsliding Study. Since it is not available, we must infer from the fuel property trends between 2006 and 2016 the effects of ethanol for conventional areas.

First, we must attempt to isolate fuel changes that result from changes other than ethanol volumes. To do this, we evaluate other fuel regulations that can also have an influence on fuel properties. Other than the RFS, three fuel regulations were promulgated by EPA in the approximate 2006-2016 timeframe. The three fuel regulations are the Tier 2/Sulfur regulation[13], the Mobile Source Air Toxics (MSAT) rule[14], and the Tier 3/Sulfur regulation.[15] The Tier 2 sulfur regulation, however, was fully implemented by calendar year 2006, so changes in fuel properties for that rule should not affect fuel properties between 2006 and 2016.[16] The MSAT rule required benzene levels to be reduced starting in 2011.[17] The MSAT rule required the reduction in benzene levels from a baseline of around 0.97% to 0.62%.[18] EPA expected an equivalent reduction in aromatics levels since benzene is an aromatic (a reduction of 0.35% in aromatics).[19] Therefore, we could infer that 0.35% of the 6.5% reduction in aromatics between 2006 and 2016 was due to the MSAT rule. The third regulation was the Tier 3/Sulfur rule, which further reduced sulfur levels to 10 ppm in 2017. Some refiners would have implemented this requirement early to

---

[11] *Fuel Trends Report*, Page 8.

[12] *Fuel Trends Report*, Page 61.

[13] *Control of Air Pollution From New Motor Vehicles: Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements; Final Rule*, 40CFR Parts 80, 85, 86, February 10, 2000.

[14] *Control of Hazardous Air Pollutants From Mobile Sources; Final Rule,* 40CFR Parts 59, 80, 85, 86, February 26, 2000.

[15] *Control of Air Pollution From Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards; Final Rule,* 40CFR Parts 79, 80, 85, et.al., April 28, 2014.

[16] *Tier 2/Sulfur*, Page 6698.

[17] *MSAT Rule*, Page 8428.

[18] *Control of Hazardous Air Pollutants from Mobile Sources, Regulatory Impact Analysis,* EPA420-R-07-002 February 2007, Page 6-6.

[19] *MSAT RIA*, Page 6-82.

generate credits, however, examination of the Reference and Control fuel properties in the Regulatory Impact Analysis shows little change in fuel properties other than sulfur.[20] Therefore, it is reasonable to attribute most of the fuel property changes between 2006 and 2016 to the expansion of ethanol in conventional areas.

In addition to fuel property regulation, changes in the ratio of gasoline and diesel production can also affect properties such as the E300 level. Specifically, if refiners increase diesel output, they shift some of the higher molecular weight components that are used in gasoline to diesel fuel. This shift can result in a gasoline with higher E300, or lower T90. With regard to E300 trends, EPA's Fuels Trends Report indicated:

- "E200 and E300 are also affected by the addition of ethanol. Ethanol boils below 200 Fahrenheit, and also causes some of the hydrocarbons in gasoline which boil above 200 Fahrenheit to boil below 200 Fahrenheit. Ethanol likely contributed to increased E300 values between 2000 and 2016 as well. However, as discussed above, the modest dieselization trend here in the United States also may have contributed to increased E300 over this time period. "

The MOVES model utilizes the following inputs in estimating fuel correction factors:

- Ethanol
- Aromatics
- RVP
- T50
- T90

Table 4 compares the EPA Anti-backsliding fuel changes to the EPA Fuels Trend Report average levels for 2016 for the five properties used in MOVES.[21]

**Table 4. Change in Fuel Properties Due to Expansion from E0 to E10 Fuel in Conventional Areas**

| Fuel Parameter | EPA Anti-backsliding Study (Summer) | EPA Fuels Trends Report – Conventional Gasoline (Summer)[22] |
|---|---|---|
| Ethanol (%) | +10 | +9.5 |
| Aromatics (%) | -2.02 | -6.5 |
| RVP (psi) | +1.0 | +0.9 |
| T50 (F) | -6.34 | -16.3 |
| T90 (F) | -1.77 | -13.6 |

[20] *Control of Air Pollution from Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards Final Rule, Regulatory Impact Analysis,* EPA-420-R-14-005, March 2014. See Tables 7-9 and 7-10.

[21] For purposes of this analysis, we ignored the small effect of the MSAT rule on aromatics.

[22] These were determined by visual observations of the plots in the Trends Report, since the raw data were not available in the report.

While the increase in ethanol and RVP are very close in both cases, the changes in the other fuel properties are very different. Specifically, the changes for the Anti-backsliding Study are much smaller than the actual data of fuel properties in conventional areas.[23] Assuming that most if not all of the fuel parameter changes are due to the expansion of ethanol in conventional areas, the actual values from conventional areas are preferable for modeling the impacts of the RFS than modeled values from all conventional and RFG areas.[24]

Using the more appropriate Fuels Trend data from conventional gasoline areas for E0 in 2006 (with three adjustments – benzene, sulfur, and T90) and E10 in calendar year 2016, AIR estimated the change in annual emissions inventories in conventional gasoline areas using the MOVES model. Fuel property adjustments used in this analysis as compared to the EPA analysis are shown in Table 5 (i.e., the rows called "Data"). For sulfur and benzene for E10, we used MOVES values by county for 2016. For sulfur and benzene for E0, we assumed the same sulfur and benzene levels as for E10.[25] For T90, we assumed that one-half of the change in T90 is due to ethanol blending, and the other half is due to the dieselization trend mentioned by EPA. For example, Table 5 shows that increasing from E0 to E10 reduced aromatics by 6.5%. Therefore, to predict hypothetical E0 aromatics levels in conventional areas in 2016, aromatics is increased by 6.5%.

**Table 5. EPA and AIR, Inc. Evaluation of Fuel Properties of E10 relative to E0 in Conventional Gasoline Areas**

| Season | Source | RVP | Aromatics | Olefins | T50 | T90 |
|---|---|---|---|---|---|---|
| Summer | EPA | 1.0 | -2.02 | -0.46 | -6.34 | -1.77 |
| | Data | 0.9 | -6.5 | -2.0 | -16.3 | -6.8 |
| Winter | EPA | 1.0 | -3.65 | -2.07 | -9.96 | -2.45 |
| | Data | 0.2 | -6.0 | -2.8 | -12.2 | -6.8 |

We compare the percent changes in annual emissions with EPA's Anti-backsliding Study in Table 6. In our emissions analysis, similar to EPA's, we also did not include California.

---

[23] If the changes in fuel parameters are not mostly related to the expansion in ethanol, it is critical to explain what factors besides ethanol are influencing these changes. We know it is not the fuel sulfur or MSAT regulations.

[24] EPA based its ethanol impacts on fuel parameters on refinery batch data from 2007, 2009, and 2011 for both RFG and conventional areas. No one outside of EPA has been able to review this analysis in detail. EPA could, at a minimum use, have used a wider range of data (for example, from 2007-2016), and also analyzed conventional areas separately from RFG areas.

[25] Benzene was reduced in the 2012-2016 timeframe, and although Tier 3 sulfur was not reduced until 2017, some reductions could have occurred prior to 2016. Neither regulation had a significant effect on aromatics, T50, or T90 levels, so we assumed the same levels for both fuel properties for E0 and E10.

| Table 6. Percent Changes in National On-Road Gasoline Emissions Due to E10 in Conventional Areas (Excludes California) | | |
|---|---|---|
| | EPA Anti-backsliding | Using Actual Fuel Properties for Conventional Areas |
| NOx | +6% | +3.1% |
| VOC | +6.6% | +1.8% |
| PM2.5 | +1.3% | -3.0% |
| CO | -5.6% | -7.3% |
| Benzene | -12.4% | -15.2% |
| 1,3 Butadiene | -12.2% | -13.8% |
| Acetaldehyde | +110% | +79% |
| Acrolein | +8.5% | +2.1% |
| Formaldehyde | +7.4% | +7.6% |

Table 6 shows that using ethanol effects based on actual fuel properties has a significant effect on the change in emission inventories. VOC, NOx, acetaldehyde, and acrolein increase much less than in the EPA analysis. Fine particulate flips from a 1.3% increase to a 3.0% decrease. Carbon monoxide shows a greater decline. The benzene decline is even more substantial –15.2%. 1,3 butadiene also shows a greater decrease.

These emission inventory changes would alter the EPA air quality analyses as well, although it is difficult to predict whether ozone would increase or decrease. At a minimum, the already very small increase in ozone in the EPA analysis would shrink further. Fine PM may show widespread air quality reductions due to E10.
In sum, as contrasted with real-world fuels data, EPA's Anti-backsliding Study overstates adverse emissions impacts associated with a transition from E0 to E10 and underestimates the benefits for air toxics, particulate matter, and carbon monoxide.

b. *EPA's Fuel Correction Factors in MOVES*

AIR previously outlined its concerns with the EPA MOVES fuel correction factors in an SAE paper. [26] For PM, EPA failed to take into account the influence of the T70 parameter on PM emissions. The EPAct testing program used by EPA to evaluate the MOVES fuel correction factors evaluated T50, T90, aromatics, and ethanol's effects on emissions. The fuels were match-blended in the testing program. Since ethanol affects all of these fuel properties, the test fuel blender adjusted T70 of some of the test fuels in an attempt to get the other distillation properties to match. The T70 values of some of the fuels were outside of the range of properties that would be seen in the U.S. Ignoring T70's effect on PM emissions attributed the T70 effect to

[26] *Analysis of EPAct Emission Data Using T70 as an Additional Predictor of PM Emissions from Tier 2 Gasoline Vehicles*, T. Darlington, D. Kahlbaum, S. Von Hulzen, and R. Furey, SAE2016-01-0996, April, 2016. Available for purchase from SAE at https://www.sae.org.

other fuel properties in the modeling, including ethanol. AIR re-analyzed the EPAct data using T70, and ethanol dropped out of the equation used to predict Bag 1 (cold start) PM emissions. The paper concludes that if T70 were included in the model predicting PM emissions, that E10 would reduce PM emissions instead of increasing PM. AIR recommended including the T70 parameter for PM emissions in MOVES.

If T70 were included in the MOVES fuel correction factors, the modeled PM emissions would be reduced even further from the level shown in Table 5 (see Figure 9 of the T70 report).

Additional commentary on the fuel correction factors in MOVES is addressed in the attached "Review of U.S. EPA's Analysis of the Emissions Impacts of Providing Regulatory Flexibility for E15," Trinity Consultants, previously submitted by Growth Energy on the 2019 E15/RVP Proposed Rule.

## 3. Discussion

EPA's Anti-backsliding analysis shows that increasing ethanol from E0 to E10 in the U.S. had very little impact on ozone and PM, and reduced the most potent air toxics (benzene and 1,3 butadiene). The emission inventory analysis, which drives the air quality results, hinges on the quality of prediction of E0 properties in calendar year 2016 in conventional gasoline areas, and the MOVES fuel correction factors. EPA's analysis of E0 properties in 2016 is based on an analysis of refiner gasoline batch processing data (also used in MOVES) for conventional and RFG areas. Real data on fuel parameter changes in conventional gasoline areas do not confirm EPA's analysis. Instead, the real fuel trends data in conventional areas show a larger effect of ethanol on key fuel properties such as aromatics, T50, and T90 levels than EPA has estimated and used in the emission inventory analysis. Using real-world fuel properties, emissions associated with E10 vs. E0 are lower across the board, with even more dramatic decreases of potent air toxics and significant CO and PM decreases.

EPA's proposed determination is that it is not necessary to promulgate fuel regulations to mitigate the air quality impacts resulting from required renewable fuels volumes. Although EPA's analysis amply supports this proposed determination, improving the analysis with ethanol fuel effects data and improved MOVES correction factors would show that the modest adverse impacts EPA observed are lessened or entirely absent. An improved analysis based on real fuel data would show ethanol-blended fuels are associated with PM improvements, lower benzene and 1,3 butadiene, and lower carbon monoxide emissions.

# Appendix 1

# Review of U.S. EPA's Analysis of the Emissions Impacts of Providing Regulatory Flexibility for E15

Prepared For:
Growth Energy

Prepared By:
Jim Lyons

TRINITY CONSULTANTS
3301 C Street, Suite 400
Sacramento, CA 95816
916-444-6666

April 29, 2019

# SUMMARY

On March 21, 2019, the U.S. Environmental Protection Agency (EPA) published a Notice of Proposed Rulemaking addressing modifications to fuel regulations to provide flexibility for E15.[1] The proposed flexibility for E15 blends involves extending the current 1 pound per square inch (psi) RVP tolerance available for E10 blends[2] to E15. More specifically, the proposed E15 flexibility provisions would revise the current maximum allowable summertime RVP limit of 9 psi for E15 to 10 psi, the same limit that applies to E10 blends.

EPA has proposed, among other things, to modify its interpretation of Clean Air Act section 211(h)(4) as applying the 1.0 psi RVP tolerance to gasoline ethanol blends of 10% or more, and also to update its interpretation under section 211(f)(1) of what is "substantially similar" ("sub sim") to certification fuel utilized in certification to include E15 at 10.0 psi. Specifically, EPA is proposing to find that E15, whether with an RVP of 9 or 10 psi, is substantially similar to the E10 fuel used in the certification of Tier 3 vehicles (which has an RVP specification of 9 psi).

EPA's emissions analysis is comprised of (1) an evaluation of whether E15 is sub sim to E10 certification fuel; and (2) a discussion of the overall impact of the proposed rule. First, in analyzing whether E15 is substantially similar to E10 certification fuel, EPA evaluated the potential impacts of E15 relative to E10 on exhaust emissions, materials compatibility, and driveability. Overall, EPA found that the exhaust emissions impacts of E15 as compared to E10 would be slight, that there would be no impacts on driveability and materials compatibility, and that, consistent with its established practice, a fuel qualifies as sub sim if its volatility meets ASTM specifications. Based on this analysis, EPA concludes that E15 is substantially similar to E10 certification fuel. These findings are also consistent with those made previously by EPA in authorizing the use of E15 in model year (MY) 2001 and later vehicles.[3,4]

Second, regarding the overall emissions impacts of the rule with respect to evaporative emissions, EPA observed that E15 at 10 psi is *less* volatile than E10 at 10 psi, which is the fuel it would likely replace. Therefore, the proposed rule would lower the volatility of in-use gasoline and reduce evaporative emissions. In addition, EPA finds that the additional dilution associated with E15 relative to E10 will reduce evaporative emissions of benzene, a toxic air contaminant. With respect to exhaust emissions, relying on the EPAct models, EPA suggested that E15 blends may result in slightly lower CO emissions, which can play a role in ozone formation, and slightly higher NOx and PM emissions.

This report provides input regarding EPA's technical emissions analyses and conclusions that E15 is sub sim to E10 certification fuel, as well as the overall emissions impact of the proposed rule. The results of the review support EPA's overall findings that E15 is substantially similar to E10 certification fuel and that any impacts of the proposed rule on emissions will be, at most, small. This conclusion that E15 and E10 will have similar emissions effects applies to Tier 3

[1] 84 Fed. Reg. 10,584 – 10,630 (Mar. 21, 2019).
[2] See Section 211(h)(4) of the Clean Air Act.
[3] 75 Fed. Reg. 68,094 (Nov. 4, 2010).
[4] 76 Fed. Reg. 4,662 (Jan. 26, 2011).

vehicles certified using E10 as well as MY 2001 and later gasoline-fueled light-duty vehicles certified using E0. However, due to shortcomings in the EPAct study methodology on which EPA relies, this review also indicates that the small increases in exhaust emissions of some pollutants that EPA reports as possible from the proposed rule are less certain to exist than EPA asserts and may in fact not actually occur—EPA should acknowledge this uncertainty in the final rule. In addition, this review confirms that the reductions in general evaporative emissions as well as evaporative emissions of benzene and emissions of carbon monoxide that EPA suggests will in fact occur.

## REVIEW OF EPA'S EMISSIONS ANALYSES

### Exhaust Emissions

With respect to both its sub sim interpretive rule and the overall emissions impact of the proposed rule, EPA's analysis of the exhaust emission impacts of E15 relative to E10 relies heavily upon statistical models that were developed using vehicle emissions data collected as part of the "EPAct study." The EPAct study involved testing of 15 MY 2008 vehicles designed with port fuel injection systems (PFI) that were certified using Indolene fuel to Tier 2 emission standards on a suite of specially blended test fuels in order to determine the impact of changes in RVP (or Dry Vapor Pressure Equivalent, DVPE), ethanol and aromatic content, as well as the temperatures at which 50% (T50) and 90% (T90) of a fuel is evaporated.

Based on the statistical models derived from the analysis of EPAct emissions test data and test fuel properties, EPA concludes that the proposed rule could result in slightly lower emissions of carbon monoxide (CO), slightly higher emissions of oxides of nitrogen (NOx) and particulate matter (PM), and small but variable impacts on emissions of non-methane organic gases (NMOG) from vehicles in which E15 has been approved for use, as EPA reports in Table II.E-1. EPA characterizes these impacts as real but relatively small. EPA emphasizes the results from the EPAct statistical models over results from other studies that used different methodologies to evaluate E15's exhaust emissions impacts. The agency also cites results from the MOVES model, Complex Model, and Predictive Model as supporting the conclusions it draws from the EPAct models. [5] As discussed in more detail below, the exhaust emissions impacts of providing E15 flexibility through the proposed action will be at most small.[6] Further, given the results of

---

[5] EPA references the Complex Model and the Predictive Model as supportive of these conclusions regarding emissions increases and decreases; however, the ability of those models to accurately show emissions differences between E10 and E15 is limited or nonexistent. EPA developed the Complex Model as part of the Reformulated Gasoline regulations based on testing of vehicles representative of MY *1990* vehicle emission control technology for which use of E15 is not authorized. In addition, the test data used to develop the model were limited to ethanol gasoline blends of up to only E10. Similarly, the Predictive Model developed by the California Air Resources Board is based on test data from blends only up to E10 and addresses impacts from the entire light-duty vehicle fleet, including vehicles for which E15 has not been approved.

[6] It should be noted that the emission impacts presented by EPA from the EPAct models in Table II.E-1 apply only to the MY 2001 and later light-duty vehicles for which E15 use has been approved. The small emission changes noted in the table, even if accurate, should be viewed in light of overall emissions of these pollutants from *all* onroad vehicles, including those that cannot legally use E15 and therefore to which the emissions impacts do not apply. Depending on the pollutant and the year, the contribution of other vehicles to total on-road emissions varies but currently is generally on the order of 50% (NMOG, CO) to 75% (PM, NOx).

other studies and issues with the data that underlie the EPAct models, it is not clear that there will be, in fact, *any* increase in exhaust emissions of NOx, PM, or NMOG associated with the proposed rule.

There has been considerable debate regarding the basis for and performance of the EPAct models, which underlie the MOVES model. Major criticisms of the EPAct models relate to the design of the test fuel matrix for study; the way in which the test fuels were "match blended" in an effort to independently vary certain fuel properties; and the resulting properties of the test fuels, particularly their distillation curves and the amounts and types of aromatic compounds they contain relative to commercial fuels. In addition, EPA assumes that the emission results observed from testing of vehicles certified to Tier 2 standards will also apply to vehicles certified to Tier 3 standards.

Beyond the studies referenced by EPA in its assessment of the proposed rule, there are numerous notable publications that document the debate surrounding the EPAct models with respect to the emissions impacts of ethanol blends and that address issues pertaining to the exhaust emissions impacts of the proposed rule. These include the publications listed below.

- Anderson, J.E., et al., "Issues with T50 and T90 as Match Criteria for Ethanol-Gasoline Blends," Society of Automotive Engineers Technical Paper Series, Paper No. 2014-01-9080.

- Darlington, T.L., et al., "Analysis of EPAct Emission Data Using T70 as an Additional Predictor of PM Emissions from Tier 2 Gasoline Vehicles," Society of Automotive Engineers Technical Paper Series, Paper No. 2016-01-0996.

- Request for Correction of Information, submitted on behalf of the State of Kansas, the State of Nebraska, the Energy Future Coalition, and the Urban Air Initiative, Concerning the U.S. Environmental Protection Agency's EPAct/V2/E-89 Fuel Effects Study and Motor Vehicle Emissions Simulator Model (MOVES2014).[7]

- Agency Response to Request for Correction of Information Petition #17001 Concerning the EPAct/V2/E-89 Fuel Effects Study and the Motor Vehicle Emissions Simulator (MOVES2014), Developed by The USEPA Office of Transportation and Air Quality.[8]

- "California Multimedia Evaluation of Gasoline Ethanol Blends between E10 and E30, Tier 1 Report," Submitted by the Renewable Fuels Association and Growth Energy to the California Multimedia Working Group, February 14, 2019. (See excerpt in Appendix A.)

- Clark, N., et al., "Emissions from Low- and Mid-Level Blends of Anhydrous Ethanol in Gasoline," Society of Automotive Engineers Technical Paper Series, Paper No. 2019-01-0997.

[7] Available at https://www.epa.gov/quality/epa-information-quality-guidelines-requests-correction-and-requests-reconsideration#17001.
[8] Available at https://www.epa.gov/sites/production/files/2018-09/documents/ethanol-related_request_for_correction_combined_aug_31_2018.pdf.

These studies encompass evaluations of the impacts in MY 2001 and later vehicles, including Tier 2 and Tier 3 vehicles. One key concern with the basis for the EPAct models identified in the literature above is how the design of the study sought to independently assess the impacts of ethanol content and T50 on vehicle emissions. As is well-known and documented in detail in the references listed above, addition of 10% or 15% ethanol to a gasoline blend substantially reduces T50, which necessitates the addition of heavier, higher-boiling hydrocarbons to the gasoline if one seeks to restore T50 to its original value, as was the case in the EPAct study. The EPAct study also attempted to independently vary RVP/DVPE, aromatic content, and T90. Table 1 presents the correlation matrix for the EPAct test fuels. Values closer to 1 or -1 indicate greater positive or negative correlations between fuel properties, while values close to zero indicate no correlation. As shown in Table 1, fuels with higher ethanol content were correlated with T50 and DVPE. This is important because it means that statistical analysis of ethanol impacts on emissions using the EPAct data cannot be completely isolated from impacts actually associated with T50 or the changes to the base gasoline that were made in the attempt to hold T50 and DVPE as constant as possible. These correlations between variables can confound the analysis of data from emissions testing programs that seek to examine fuel-related effects, and this confounding is not necessarily eliminated by the type of statistical analysis performed to develop the EPAct statistical models. This is shown, for example, in the analysis presented by Darlington et al., where substitution of one distillation variable for another in a re-analysis of the EPAct data leads to the conclusion that E15—made by slash-blending ethanol and thus without other base gasoline adjustments to increase T50—will result in *reductions* in PM emissions, rather than the increase in PM emissions predicted by the EPAct models.

**Table 1**
**Correlation Matrix for EPAct Test Fuel Design Variables**

| | EtOH | DVPE | T50 | T90 | Aromatics |
|---|---|---|---|---|---|
| EtOH | 1.00 | -0.10 | -0.56 | 0.02 | -0.04 |
| DVPE | | 1.00 | -0.30 | 0.13 | 0.05 |
| T50 | | | 1.00 | -0.04 | -0.07 |
| T90 | | | | 1.00 | -0.01 |
| Aromatics | | | | | 1.00 |

Given the above, there is reason to believe, as is discussed in detail by Anderson et al., that the EPAct study design caused emissions impacts due to changes in the base gasoline made in the attempt to hold other fuel properties, in particular T50, constant, and not due to the addition of ethanol itself to an otherwise unaltered blendstock. As noted by Clark et al., in normal practice it is not possible to add ethanol to a gasoline blendstock while keeping other properties, such as T50, constant. Finally, in the "real world," ethanol is splash-blended into gasoline blendstocks to make E15, and there is no reason to believe that refiners will seek to make adjustments to these blendstocks to hold distillation properties such as T50 constant. Accordingly, evaluating the effect of E15 while allowing properties such as T50 to vary is a more realistic representation of what will result in practice than the approach used to blend the fuels used in the EPAct study.

To put this in context, the primary effect of the proposed rule, at least in the near- to mid-term, will be that additional ethanol will be added to E10 fuels or to gasoline blendstocks designed for use with ethanol. As noted above, this "splash blending" will affect other fuel properties besides ethanol content and will have impacts on exhaust emissions. In the long-term, changes in blendstocks may be made to take advantage of, for example, the higher octane content of E15; those changes, however, will be made based on refinery economics, not as part of an effort to hold T50 and other fuel properties constant.

As noted above, the EPAct models are based on data from match-blended gasoline; however, EPA has used these models in an attempt to account for splash blending of E15 from E10 by estimating the RVP, T50, T90, aromatic, and ethanol content of resulting E15 fuels and found, as shown in Table II.E-1, that impacts on emissions will be small. However, given the issues raised above with the EPAct models, the agency should not ignore the results from studies other than EPAct, particularly those that have relied on splash blending to prepare test fuels as occurs in the real world.

As noted by Anderson et al., numerous studies based on splash blending have shown reductions in exhaust emissions of non-methane hydrocarbons (NMHC) and PM. In addition, the review and analysis of studies other than EPAct included in the California Multimedia Evaluation found no statistically significant impacts or statistically significant reductions in exhaust emissions of organics (e.g., NMOG), NOx, CO, PM, or potency-weighted emissions of air toxics (based on California risk factors) from E15 relative to either E10 or E0. Those findings are reported in Table 7 of that review and are reproduced below. Of particular note in that review is the wide range of vehicle model years and technologies spanned (MY 2001 to 2017 vehicles certified to California Air Resources Board [CARB] LEV I, LEV II, or LEV III, and/or EPA Tier 2 and Tier 3 standards using both PFI and gasoline direction injection [GDI] fuel systems) by the studies considered and the consistency of the assessment of the findings across those studies.

**TAILPIPE EMISSIONS STUDIES ON E15 VERSUS EITHER E10 OR E0 AS BASE FUEL**

| Study Name | Test Cycle | No. of Vehicles | Vehicle Model Years | Base Fuel and Blending Strategy | $NO_x$ | Organic Emissions | CO | PM mass emissions | Potency Weighted Toxics |
|---|---|---|---|---|---|---|---|---|---|
| **DOE Intermediate Fuel Blends** | LA-92 | 13 | 2001-2007 | E10 splash blend | No significant difference | No significant difference | No significant difference | Not tested | Not tested |
| **DOE Catalyst Study** | FTP | 24 | 2003-2009 | E0 splash blend | No significant difference | No significant difference | ↓ | Not tested | Not tested |
| **UC Riverside -1** | UC and FTP | 7 | 2007-2012 | E10 match blend | No significant difference | No significant difference | No significant difference | No significant difference | No significan difference |
| **UC Riverside -3** | LA-92 | 5 | 2016-2017 | E10 low aromatics splash | ⇣ | ↓ | No significant difference | No significant difference | ↓ |
| **UC Riverside -3** | LA-92 | 5 | 2016-2017 | E10 low aromatics match blend | No significant difference | No significant difference | No significant difference | No significant difference | No significan difference |
| **UC- Riverside-3** | LA-92 | 5 | 2016-2017 | E10 high aromatics match blend | No significant difference | No significant difference | No significant difference | No significant difference | No significan difference |
| **All Data (no. of datapoints for each pollutant in parentheses)** | Various | | 2001-2017 | Various | No significant difference (66) | NMHC:No significant difference (42) THC:No significant difference (29) NMOG:No significant difference (24) | ↓ (66) | No significant difference (24 ) | No significan difference (22 ) |

Source: Table 7, California Multimedia Evaluation of Gasoline Ethanol Blends between E10 and E30, Tier 1 Report.

Clark et al. also highlight the issues associated with the analysis of emissions data from match blending studies like EPAct. In addition, they note the difficulties in assessing the impacts of changes in fuels, such as moving to E15 from E10, given that impacts vary from vehicle to vehicle based on the relatively small changes in emissions differences in vehicle technology and calibration strategies, the generally low emissions levels from vehicles, and the actual properties of fuels on which the vehicles would operate.

In addition to the EPAct models, EPA discusses the Coordinating Research Council (CRC) E-94-2 and E-94-3 studies with respect to the impact of the proposed rule on PM emissions. These studies investigated the impacts of ethanol at levels up to E10 and PM Index on exhaust emissions from MY 2010 to 2015 vehicles with GDI engines certified to EPA Tier 2 and/or CARB LEV II and LEV III standards, and found only statistically significant impacts of ethanol on PM emissions. EPA then assumes that the impacts on PM emissions observed from ethanol up to the E10 level can be linearly extrapolated to E15; based on this assumption, EPA concludes that PM emissions from GDI vehicles on E15 would increase by 10% relative to E10. Although EPA's focus on GDA vehicles is appropriate, given their increasing prevalence in the market, there are currently no data supporting EPA's hypothesis that the emissions observed from ethanol up to E10 can be linearly extrapolated from E10 to E15.

In fact, another study performed by "CE-CERT" on MY 2016 and 2017 vehicles certified to CARB LEV III and/or EPA Tier 3 standards that is briefly discussed by EPA found no statistically significant effects of E15 on exhaust emissions of NOx, NMHC, or PM emissions relative to E10. EPA appears to critique the validity of the results because T50, a variable found to be important in the EPAct Study, varied due to the addition of ethanol and there was no effort made to control it as in the EPAct study; however, T50 will in fact vary in the splash blending scenario expected for actual fuels in the real world. EPA provides no explanation for why refiners would seek to compensate by reformulating the base gasoline to counteract the effects of splash blending ethanol on T50, and real-world experience with E10 contradicts such an approach. In particular, given that this study actually investigated E15 impacts using fuel blending strategies representative of real-world fuels, EPA should focus on the results of this study on PM emissions, rather than speculation based on the CRC E-94-2 and E-94-3 studies, which did not include actual testing of E15. At the very least, EPA should acknowledge that the existence of PM emissions impacts due to E15 relative to E10 is uncertain and could depend on whether characteristics such as T50 change due to the addition of ethanol or whether refiners would compensate for the impact of adding ethanol on such characteristics by altering the base gasoline formulation.

Overall, although all of the available data, including the EPAct study and related models, reasonably establish that the exhaust emissions impacts will be at most slight, there is reason to suspect that there will not actually be any negative emissions impacts associated with the proposed rule. Given this, EPA should at least acknowledge that there is a question of whether there will be any adverse impacts on NOx or PM emissions resulting from the proposed rule.

**Evaporative Emissions**

In assessing the overall emissions impacts of its proposal, EPA also performs an analysis of the potential impact of the proposed rule on evaporative emissions. In its analysis, EPA assesses the impacts of E15 relative to E10 on the following six main "components" of evaporative emissions:

1. Diurnal emissions;
2. Refueling emissions;
3. Hot soak emissions;
4. Running loss emissions;
5. Permeation; and
6. Unintended leaks.[9]

EPA first concludes that E15 will not impact evaporative emissions arising from permeation, hot soak, or unintended leaks relative to E10. The agency then discusses impacts on diurnal, refueling, and running loss emissions in the context of potential E15 RVP levels in comparison to E10 RVP levels.

With respect to summertime E15 blends made from the same gasoline blendstocks as E10 that is currently subject to the 1 psi RVP tolerance, EPA concludes that the proposed rule will likely have no impact and may in fact slightly *decrease* diurnal, refueling, and running loss emissions. This conclusion is based on data showing that the actual RVP level of E15 at 10 psi is 0.1 psi lower than E10 at 10 psi.

In addition, EPA finds that evaporative emissions of the Mobile Source Air Toxic benzene may also be lower with E15 due to the additional dilution of the gasoline blendstock relative to E10. EPA similarly concludes that E15 at 9.0 psi RVP will not impact evaporative emissions relative to E10 at 9.0 psi RVP, since the volatility is the same. EPA's analysis and findings in these regards are appropriate as it is well-known that RVP is the key factor in determining the magnitude of evaporative emissions arising from these sources.

In addition to the above, EPA considers the impacts of E15 at 10.0 psi RVP relative to E15 and E10 at 9.0 psi RVP (even though E10 is subject to a 1 psi tolerance and is thus sold in the summer at 10 psi). For purposes of the sub sim analysis, the agency appropriately proposes to leave unchanged its historical approach to RVP in its current substantially similar interpretive rule and find that E15 is sub sim so long as its RVP is within the ASTM range. The agency notes in passing that "increasing fuel RVP from 9.0 psi to 10.0 psi increases fuel vapor generation significantly under summertime conditions, which can overwhelm a vehicle's evaporative control system and push it out of compliance." This is a significant over-generalization, and EPA should clarify in the final rule the narrow conditions under which such a difference in volatility can significantly affect evaporative emissions. Actual evaporative emissions from a given vehicle will depend on a number of factors and may be lower than expected based on certification test results, particularly for MY 2001 and later vehicles for which

[9] 84 Fed. Reg. 10,599 (Mar. 21, 2019).

E15 use has been approved. Factors affecting emissions from a particular vehicle include the following:

- Actual ambient temperatures experienced by a vehicle compared to those used in certification testing;
- The actual time between driving events that purge stored vapors from the evaporative emissions control system compared to the multi-day diurnals involved in certification testing; and
- The evaporative emissions control technology on the vehicle, including compliance margins that vehicle manufacturers have engineered into evaporative emission control systems.

First, to the extent that ambient temperatures are lower than those associated with certification testing, vapor generation and evaporative emissions will be reduced. In addition, it is well-known that vapor generation rates of ethanol blends are lower than those of gasoline not containing ethanol—where both are held to the same RVP—at temperatures below 100°F.[10] In other words, the "volatility increase" resulting from blending ethanol at 10-15% in terms of RVP is determined at 100°F and the amount of the increase in volatility is lower at temperatures below 100°F. Furthermore, more frequent driving reduces the amount of vapor stored in evaporative emission control systems relative to that during certification testing, again leading to lower emissions, as do manufacturer compliance margins. Therefore, although higher RVP levels generally lead to higher evaporative emissions, it is far from given that operation of a specific vehicle on a 10 psi RVP ethanol blend under summer conditions will either overwhelm its evaporative emission control system or push it out of compliance with applicable emission standards. EPA should acknowledge that such conditions are limited.

## **Air Toxics Impacts**

EPA's analysis focuses on evaporative emissions of benzene. However, the proposed rule does have the potential to impact emissions of other exhaust emission toxic species such as benzene; 1,3 butadiene; formaldehyde; and acetaldehyde. The overall impact of the proposed rule when assessed using appropriate weightings based on risk factors such as those available from EPA's Integrated Risk Information System (IRIS)[11] is expected to be slight. The reason for this is that increases in emissions of one compound, such as acetaldehyde (a relatively less potent air toxic), will be offset by decreases in others, such as benzene and 1,3 butadiene (which are more potent air toxics).

---

[10] Reddy, S.R., "Prediction of Fuel Vapor Generation form a Vehicle Fuel Tank as a Function of Fuel RVP and Temperature," Society of Automotive Engineers Technical Paper Series, Paper No. 892089, 1989.
[11] https://www.epa.gov/iris. The mid-point of the IRIS range for inhalation risk for benzene was used in this analysis.

## Materials Compatibility and Driveability

EPA's sub sim analysis also addresses materials compatibility and driveability of E15 as compared to E10 certification fuel. EPA refers back to its analysis in the 2010 and 2011 E15 waiver decisions that thoroughly explained the agency's findings that E15 would have no issues with respect to materials compatibility and driveability.[12] With respect to materials compatibility, EPA also notes that vehicle manufacturers have been using E15 as part of the new-vehicle certification process since at least MY 2014 to demonstrate the durability of emission control systems to conclude that impacts on newer vehicles are even less likely to be an issue.[13] EPA similarly finds that manufacturers are designing vehicles for operation on E15 and that fuel producers are ensuring that E15 complies with ASTM D4814–18c fuel specifications.[14] Accordingly, EPA appropriately finds that "E15 would have similar driveability characteristics to Tier 3 E10 certification fuel."[15] These conclusions apply equally to MY 2001 and later light-duty vehicles, including Tier 3 vehicles, as EPA documented in its earlier decisions providing partial waivers for E15 use in MY 2001 and later vehicles.

EPA's findings and analysis are supported by the fact that E15 has been in commercial use for a considerable period of time without any reports of issues with respect to either materials compatibility or driveability. In addition, the California Multimedia Evaluation includes a review of issues that could arise from use of gasoline ethanol blends above E10 and concludes that no materials compatibility impacts are expected to arise.

## Comments Regarding Scope of "Sub Sim" Determinations for E15

As demonstrated above, the available data indicate that E15 will result in at most small, if any, increases in some exhaust pollutants and lower evaporative emissions than E10 blends at the same RVP standard across a wide spectrum of vehicle vintages (from MY 2001 forward), technologies, and certification standard levels. Indeed, EPA already approved E15 for use in *all* MY 2001 and later vehicles based on a thorough analysis of the emissions, materials compatibility and driveability impacts of the fuel in its partial waiver decisions, which compared E15 (with 15% ethanol) to E0 (with no ethanol). As shown in the DOE Catalyst Study[16] on which EPA relied heavily for the partial waiver decisions, the impacts of E10 and E15 on exhaust emissions were essentially the same.

As such, and given the historical approach EPA has consistently taken to require that a sub sim fuel meet the general fuel volatility specifications in the ASTM standard, there is no basis for EPA to limit its sub sim finding to constrain use of E15 to Tier 3 vehicles. EPA can reasonably find that E15 is sub sim to E10 (or E0) in all MY 2001 and later light-duty vehicles.

---

[12] 84 Fed. Reg. 10,600 – 10,601 (Mar. 21, 2019).
[13] *Id.* at 10,600.
[14] *Id.* at 10,601.
[15] *Id.*
[16] https://info.ornl.gov/sites/publications/Files/Pub31271.pdf.

Appendix A

California Multimedia Evaluation of Gasoline Ethanol Blends between E10 and E30, Tier 1 Report

Section 4, "Use of Gasoline-Ethanol Blends in Vehicles"

# California Multimedia Evaluation of Gasoline-Ethanol Blends between E10 and E30
# Tier I Report

**Submitted to the Multimedia Working Group**

**February 14, 2019**

RENEWABLE FUELS ASSOCIATION

growth energy
America's Ethanol Supporters

# 4 Use of Gasoline-Ethanol Blends in Vehicles

As discussed in Section 1.2, since 2010, virtually all fuel sold in the United States, and all California RFG, has been E10 and few if any ill effects have been observed in the existing vehicle fleet. Given this, E10 is the appropriate basis for comparison with gasoline-ethanol blends in the E11 – E30 range. Since only

2001 and later model-year light-duty vehicles are approved to use gasoline-ethanol blends above E10 by U.S. EPA, older vehicles and non-vehicular engines, motorcycles, heavy-duty vehicles, as well as off-road vehicles such as boats and snowmobiles, which are prohibited by U.S. EPA from using higher ethanol content fuels are not considered here. Some portion of the flexible fuel vehicles (FFVs), which comprise between 5% and 10% of the on-road fleet (more than 20 million on the road in the United States[62]) that operate primarily on E10, may begin to operate on E15 and so may impact overall fleet emissions.

As is shown below, emissions and compatibility data related to the use of gasoline-ethanol blends above E20 in existing vehicles is limited. In addition, federal waivers allowing the use of blends above E15 would have to be granted by U.S. EPA in order to use blends above E15 in existing vehicles.

## 4.1 Vehicle Compatibility

### *4.1.1 Vehicle design*

Virtually all new U.S. vehicles are warrantied for use with E15 (see Section 4.2) by the Original Equipment Manufacturers (OEMs) which ensures material compatibility of the fuel system and that all emissions requirements are met when new and at full useful life. However, to ensure that older vehicles are also compatible with higher gasoline-ethanol blends, two programs have tested relatively large numbers of older vehicles for extended times on E15 and E20. (There has been no significant published data on the use of E30 in recent-model or older vehicles.)

A study undertaken in 2006 at the University of Minnesota[63] included 40 pairs of vehicles, model years 2000-2006, with matched usage patterns. One of each pair used commercially available E0, while the second was fueled with E20, made from commercially available E10 splash blended with additional ethanol. During the test period, only two vehicles in the program had maintenance issues, with only one being fuel related, and that was in an E0-fueled vehicle. Thus, the data from this program suggest that these older vehicles would not have increased maintenance issues associated with the use of gasoline-ethanol blends above E10 and up to E20.

A far more intensive program[64], overseen by the Oak Ridge National Laboratory included 82 MY 2000-2009 vehicles. Eighteen vehicle models (each represented by three matched vehicles) were aged with E0, E15 and E20; five vehicle models (each represented by four matched vehicles) were aged with E0, E10, E15 and E20; and four vehicle pairs were aged with E0 and E15. The E0 was TOP-TIER™[65] retail E0 fuel, into which ethanol was splash blended to produce the other test fuels. Each vehicle was aged the equivalent of 50,000 to more than 100,000 miles on each test fuel. The testing was conducted at three different facilities, the Southwest Research Institute (SwRI), the Transportation Research Center (TRC) and Environmental Testing Corporation (ETC). ETC is located in the Denver area and was included to assess the potential for altitude related effects.

Unscheduled maintenance was recorded, and the affected equipment was removed and analyzed for potential fuel effects. Failures of certain components, including the transmission, spark plug and radiator which had no contact with the fuel, are not included here. Fuel system repairs that were required over the course of the testing included an evaporative emissions hose, believed to be made of nitrile rubber, which split on a 2002 Dodge Durango. No differences could be detected between the inside and the outside of

---

[62] https://www.afdc.energy.gov/vehicles/flexible_fuel.html, accessed August 23, 2018.

[63] Kittleson, D., A. Tan, D. Zarling, B. Evans, C. Jewitt, Demonstration and Driveability Project to Determine the Feasibility of Using E20 as a Motor Fuel, November 2008.

[64] West, B., Sluder, C.S., Knoll, K., Orban, J., Feng, J., Intermediate Ethanol Blends Catalyst Durability Program, ORNL/TM-2011/234, February 2012.

[65] TOP-TIER™ is a fuel quality specification created and enforced by automakers. It is primarily intended to ensure that the fuel includes adequate level of detergents to avoid deposits on critical engine parts. More information can be found on the program website: www.toptiergas.com.

the hose, so the failure was attributed to general aging, rather than fuel effects. Two fuel pumps in 2006 MY vehicles (plus a fuel pump and a fuel level sender in a 2000 MY vehicle) were replaced when they failed, although the researchers determined that the failures were unrelated to fuel. In addition, all three (E0, E15 and E20) 2006 Chevrolet Impalas experienced canister vent solenoid failures.

Finally, a tear-down study[66] of the engines in eighteen of the vehicles (six makes and models from the model years 2006 to 2008, each run on E0, E15 and E20) showed an increase in intake valve deposits (IVD) in the E15 vehicles, relative to the E0 vehicles. The vehicles aged with E20 also showed an increase relative to both E15 and E0, although the results were not as consistent.
The authors hypothesize that the increase was due to the dilution of the normal detergent additives which are present in TOP TIER™ gasoline. However, these deposits were not found to result in either operational problems or increases in emissions.

Evaporative emission canister working capacities showed a slight decreasing trend with higher concentration ethanol blends for one-third of the six different models. The emissions systems of the eighteen aged vehicles were pressure checked, and all were found to have maintained their integrity. No fuel related differences were found in valve seat width, valve surface contours, fuel tanks, fuel lines and evaporative emissions lines. Fuel injector flow rates were equivalent to within +/- 3%. There were no statistically significant differences in oil consumption attributed to the ethanol level in the fuel.[67]

Emissions were measured using EPA certification E0 fuel on all vehicles at the start of the project, at one or two points, and at the end of scheduled aging. No discernible difference in aging effects from the different fuels could be found except that on those vehicles tested by ETC which showed slightly less catalyst deterioration with higher ethanol blends. One hypothesis suggested by the researchers was that the sulfur content of the fuel was lowered as the result of dilution by ethanol as the ethanol level increased, although this impact was not seen in other vehicle sets. Largely based on these test results, which showed no degradation in emissions at gasoline-ethanol blend levels up to E20, EPA has permitted the use of gasoline-ethanol blends of up to E15 in all 2001+ MY vehicles.

The CRC has conducted studies focused on finding and testing vehicles and components suspected of being most susceptible to damage from E15 and E20. One pump, identified only as Pump N, was shown to have a greater failure rate with E15 in comparison to standard E10.[68] However, confidentiality rules which limit CRC's ability to divulge the make and model of the pump, as well as the materials of which it is made, limit the usefulness of this information to the general scientific community.

In addition, the Minnesota Center for Automotive Research conducted a 30-day static soak test[69] followed by 4000-hour endurance tests[70] for eight different models of fuel pumps and three different models of sending units[71] using E20, E10 and E0 (a total of 24 pumps and 9 sending units). No fuel effects were identified during the soak test, but during the 4000 -hour endurance testing, four pumps out of the twenty-four failed – two using E10 and two using E0. The commutators[72] of several of the pumps tested in E0 wore substantially more than those tested in either E10 or E20. No evidence of negative effects of use of E20 on fuel pumps was found. All of the sending units failed during the 4000-hour endurance testing,

---

[66] Shoffner, B., Johnson, R., Heimrich, M., Lochte, M., Powertrain Component Inspection from Mid-Level Blends Vehicle Aging Study, ORNL/TM-2011/65, November 2010.
[67] West, B., Sluder, C.S. "Lubricating Oil Consumption on the Standard Road Cycle", SAE Technical Paper No. 2012-01-0884.
[68] CRC, Durability of Fuel Pumps and Fuel Level Senders in Neat and Aggressive E15, CRC Contract No AVFL-15a, January 2013.
[69] Mead, G., B. Jones, P. Steevens, N. Hanson, T. Devens, C. Rohde, A. Larson, The Effects of E20 on Automotive fuel Pumps and Sending Units, Minnesota Center for Automotive Research, February 21, 2008.
[70] Mead, G., B. Jones, P. Steevens, N. Hanson, J. Harrenstein, An Examination of Fuel Pumps and Sending Units During a 4000 Hour Endurance Test in E20, Minnesota Center for Automotive Research, March 25, 2009.
[71] The fuel sending unit is installed inside of the fuel tank. Its purpose is to measure the fuel level and send that information to the fuel gauge.
[72] A commutator is a moving part in certain types of electric motors or generators that can convert alternating current into direct current.

regardless of fuel. The authors reported no significant differences in performance or failure between the sending units as a function of test fuel.

One engine durability study was considered in this review[73] although its results were disregarded because of significant problems with its methodological and statistical approach. This study, and what we view as its methodological problems, is extensively discussed elsewhere.[74]

### 4.2 Manufacturer Warranty Limitations

FFVs are warrantied for the use of all levels of ethanol in fuel. Warranty information for use of gasoline-ethanol blends of up to E15 in non-FFVs is summarized in Figure 2 below. Other than the BMW Mini (warrantied for gasoline-ethanol blends up to E25), no past or current production vehicles have warranties allowing the use of fuels above E15.

[73] CRC, Intermediate-Level Ethanol Blends Engine Durability Study, CRC Project CM-136-09-1B, April 2012.
[74] McCormick, R.L, j. Yanowitz, M. Ratcliff, B. Zigler, Review and Evaluation of Studies on the Use of E15 in Light-Duty Vehicles, https://ethanolrfa.3cdn.net/b378858ac325c6e165_sgm6bknd4.pdf, accessed September 18, 2018.

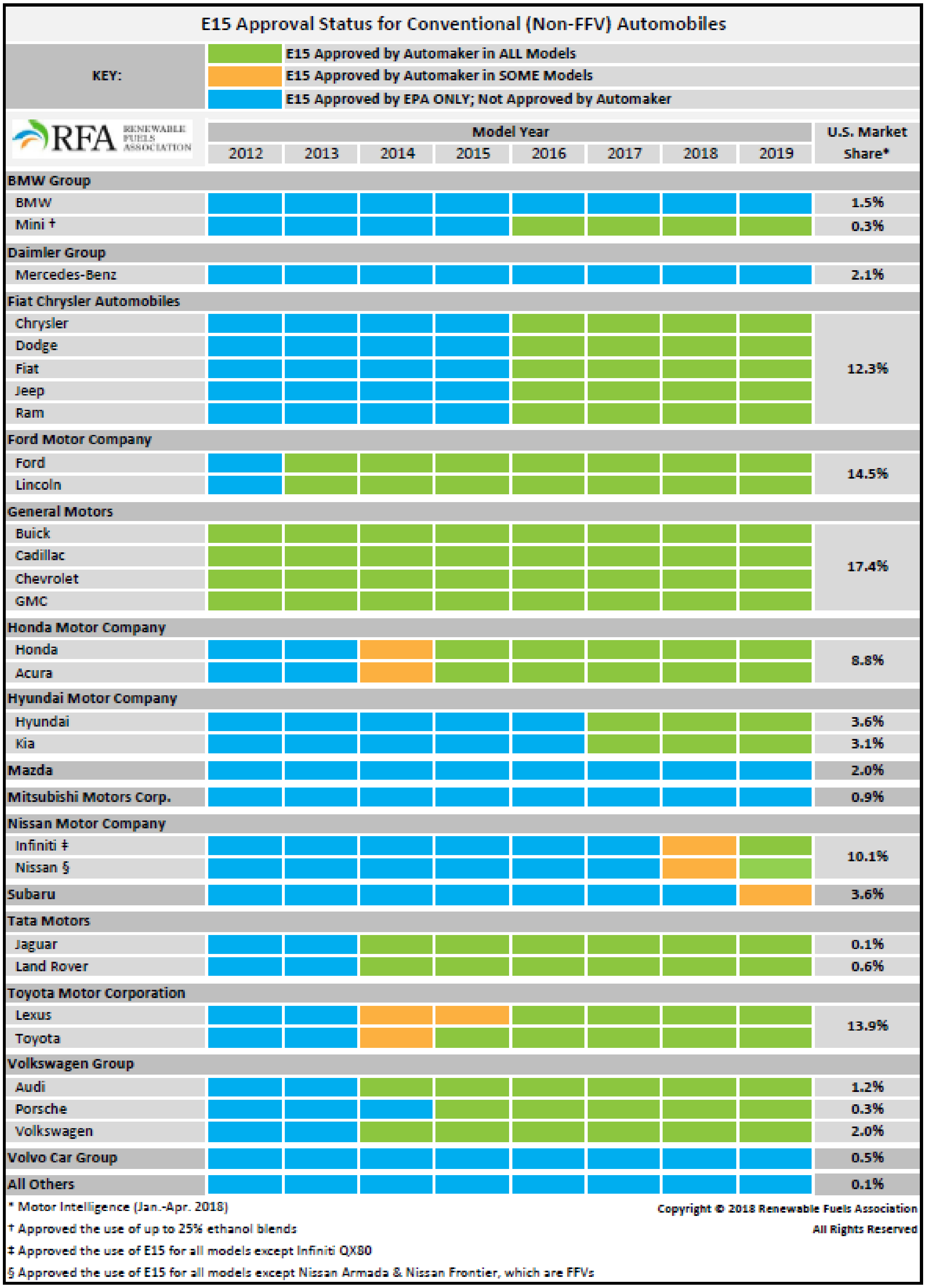



**FIGURE 2. WARRANTY INFORMATION FOR USE OF E15 IN U.S. VEHICLES**

## 4.3 Detailed Properties of Gasoline-Ethanol Blends Relevant to Use in Vehicles

The addition of ethanol to hydrocarbon gasoline changes the properties of the fuel, including its energy density, vapor pressure, octane, distillation properties and its impact on materials. Material compatibility of gasoline-ethanol blends with metals, elastomers and plastics that are used in vehicles and fuel infrastructure has been discussed in Section 3 above.

As noted in Section 1, ASTM Standard D4814-18d, specifies the properties of spark-ignition fuel and used by the Division of Measurement Standards (part of the California Department of Food and Agriculture) to set requirements for such fuels.[75] As present, this specification addresses blends up to E15 fuels so no changes would be required for CARB to approve fuels specifications covering those fuels. However, modifications would be needed for approval of blends above E15 up to E30.

The analysis of vapor pressure and octane below is based on results of a study in which the American Petroleum Institute (API) has tested a variety of fuel properties on 71 different gasolines with widely variant properties. Each gasoline was then blended with 10%, 12.5%, 15%, 20% and 30% ethanol and retested. Some of the gasolines were petroleum blendstocks intended to be used to make gasoline-ethanol blends (blendstocks for oxygenate blending or BOBs), others were intended for use without the addition of ethanol. These fuels were not selected to be representative of typical or average fuels, but rather to show the expected range of changes in properties that could occur due to the addition of ethanol to hydrocarbon fuels.

### *4.3.1 Energy Density*

Ethanol has about 67% of the energy of gasoline on a volumetric basis.[76] Because the energy density of ethanol is lower than gasoline, fuel economy tends to decrease as the ethanol content in blends increases. Modern engines can take advantage of higher octane fuels to be slightly more efficient. Table 3 below shows the relative energy density of E15, E20 and E30, relative to E10.

**TABLE 4. ENERGY DENSITY OF GASOLINE-ETHANOL BLENDS RELATIVE TO E10.**

| | |
|---|---|
| E15 | 97% of the energy of E10/gallon |
| E20 | 93% of the energy of E10/gallon |
| E30 | 90% of the energy of E10/gallon |

### *4.3.2 Vapor Pressure*

As noted in Section 3.5.1, at E10, the Reid Vapor Pressure (RVP) of the blended fuel is about 1 psi higher than that of the blendstock but is expected to decrease as the ethanol content increases as is shown in Figure 2, above.

As shown in Figures 5 and 6, the measured RVP at E15 and E20 was indistinguishable from that of an E10 using the same base gasoline blendstock using ASTM methods. Figure 7 shows that at E30, RVP is about one-half pound per square inch lower than that of an E10 made using the same gasoline blendstock.

[75] https://www.cdfa.ca.gov/dms/

[76] California Air Resources Board, Low Carbon Fuel Standard and Alternative Diesel Fuels Regulation 2018, Final Regulation Order, posted September 17, 2018, https://www.arb.ca.gov/regact/2018/lcfs18/fro.pdf accessed November 13, 2018.

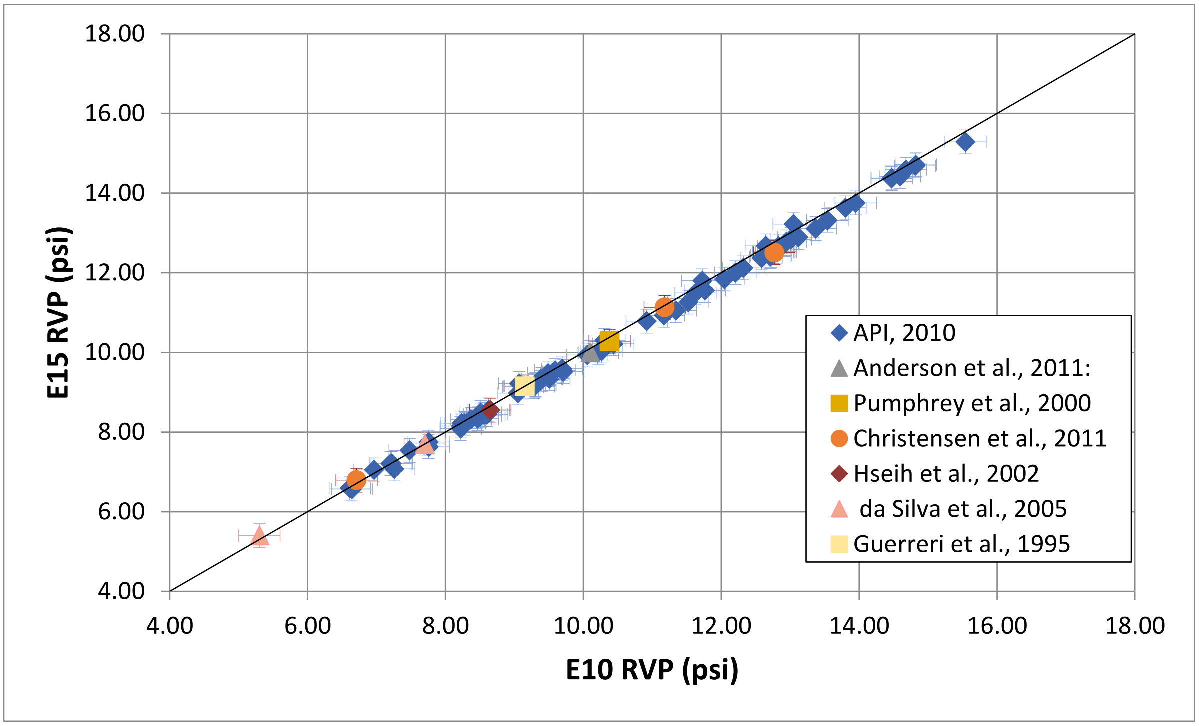



**FIGURE 3. THE VAPOR PRESSURES OF E15 AND E10 BLENDS MADE USING THE SAME BASE GASOLINE BLENDSTOCK. THE ERROR BARS SHOW THE REPEATABILITY OF THE ASTM METHOD D5191 USED TO MEASURE REID VAPOR PRESSURE.**

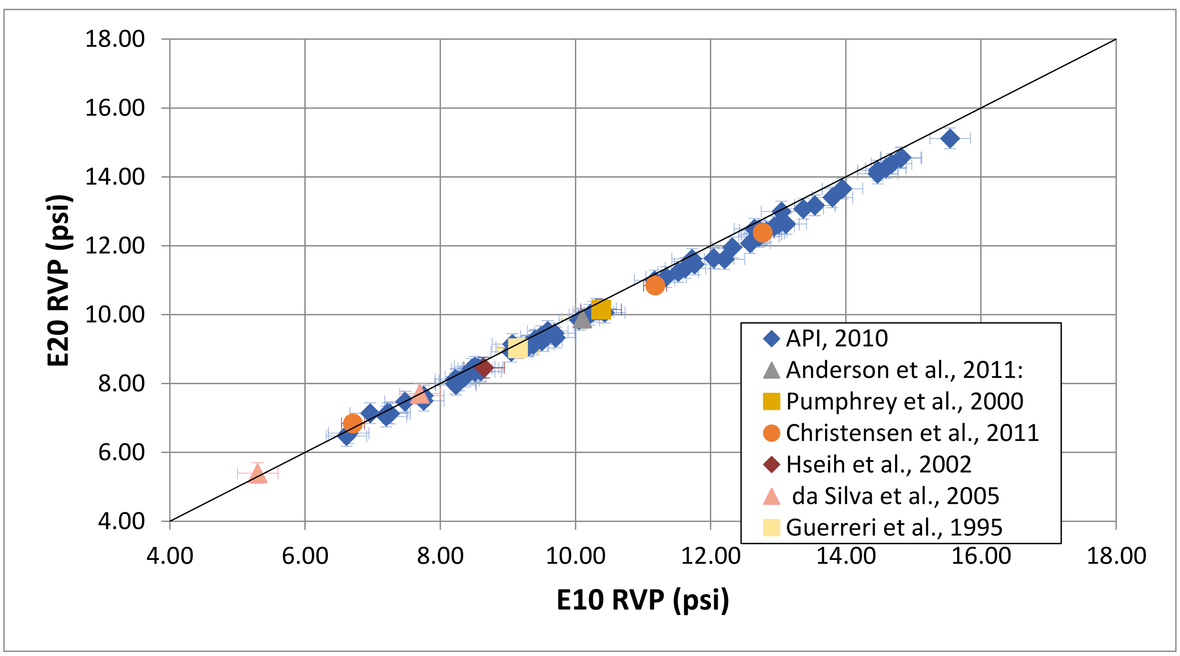



**FIGURE 4. THE VAPOR PRESSURES OF E20 AND E10 BLENDS MADE USING THE SAME BASE GASOLINE BLENDSTOCK. THE ERROR BARS SHOW THE REPEATABILITY OF THE ASTM METHOD D5191 USED TO MEASURE REID VAPOR PRESSURE.**

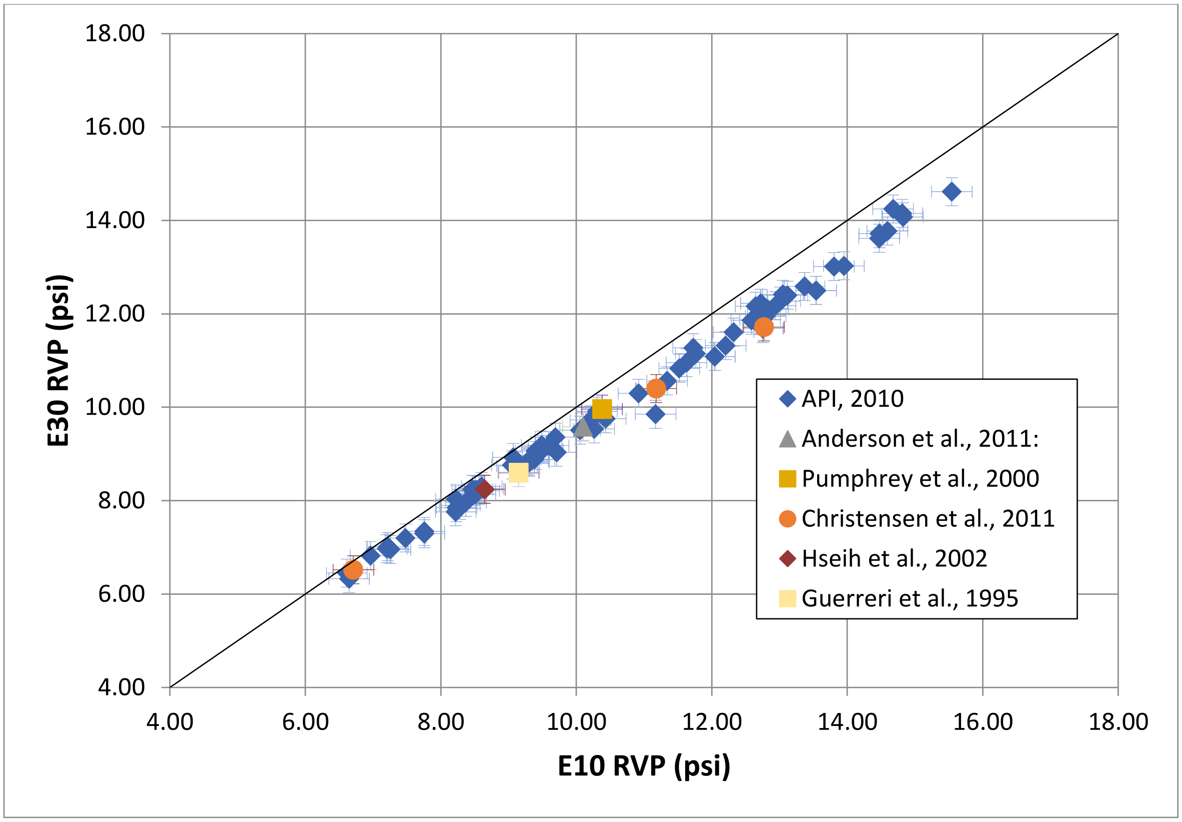



**FIGURE 5. THE VAPOR PRESSURES OF E30 AND E10 BLENDS MADE USING THE SAME BASE GASOLINE BLENDSTOCK. THE ERROR BARS SHOW THE REPEATABILITY OF THE ASTM METHOD D5191 USED TO MEASURE REID VAPOR PRESSURE.**

### *4.3.3 Octane*

Inside the cylinder of an internal combustion engine the air/fuel mixture should ignite at a precise time in the piston's stroke. Engine knock occurs when pockets of the air/fuel mixture ignite earlier than they should. A minimum octane in fuel is required to prevent engine knocking. In comparison to retail gasoline, ethanol has a high octane number. Its AKI[77] (antiknock index) is 114 while gasoline is typically sold with an octane number of between 85 and 91. Adding additional ethanol to gasoline increases the octane number, as shown in Figure 6. As mentioned above, higher octane levels of ethanol blend fuels can also reduce fuel consumption in those vehicles which optimize fuel economy by advancing ignition timing to just below the knock limit offsetting to some degree the impacts of the lower energy content of those blends.

[77] AKI is equal to the average of the research octane number and the motor octane number, which are two different ways of measuring octane. The octane number posted at the retail fuel station is the AKI.

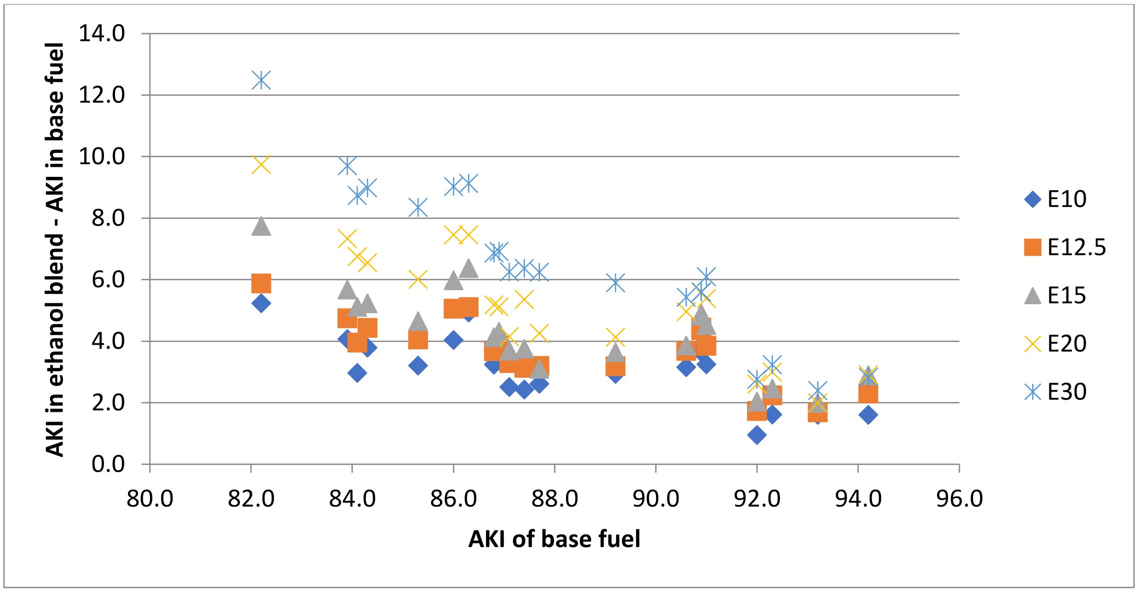



**FIGURE 6. IMPACT OF INCREASING ETHANOL CONTENT ON 71 DIFFERENT BASE FUELS.[78]**

### *4.3.4 Distillation Curve*

Gasoline and oxygenate blendstocks are complex mixtures of hydrocarbon compounds with a range of boiling points. As a result, the distillation curves of these fuels typically rise steadily upward as temperature increases and individual compounds volatilize. As shown in Figure 7, the distillation curves of ethanol-containing blends start in the same way as pure hydrocarbon gasoline, but then plateau, at a relatively constant temperature as the azeotropes[79] that form between ethanol and various hydrocarbons distill. When the ethanol is gone, the curve shoots upward to rejoin the distillation curve of the base hydrocarbon fuel, thus T10 and T90 are largely unchanged by the addition of ethanol below 30 percent by volume. At higher ethanol concentrations, the length of the plateau increases, and typically impacts T50. Thus, one should expect the T50 of virtually all E15, E20 and E30 fuels to be 5 to 10 °C less than that of E10 blended with the same base fuel.

ASTM D4814-18d allows for the expected lower T50 with E15. Higher ethanol content (i.e., above E15) fuels will not result in significantly lower T50s.

[78] American Petroleum Institute, Determination of the Potential Property Ranges of Mid-Level Ethanol Blends, Final Report, April 23, 2010 https://www.api.org/~/media/Files/Policy/Fuels-and-Renewables/2016-Oct-RFS/The-Truth-About-E15/E10-Blending-Study-Final-Report.pdf

[79] An azeotrope is a mixture of two or more liquids that have the same concentration in the liquid and vapor phase and so cannot be separated by distillation.

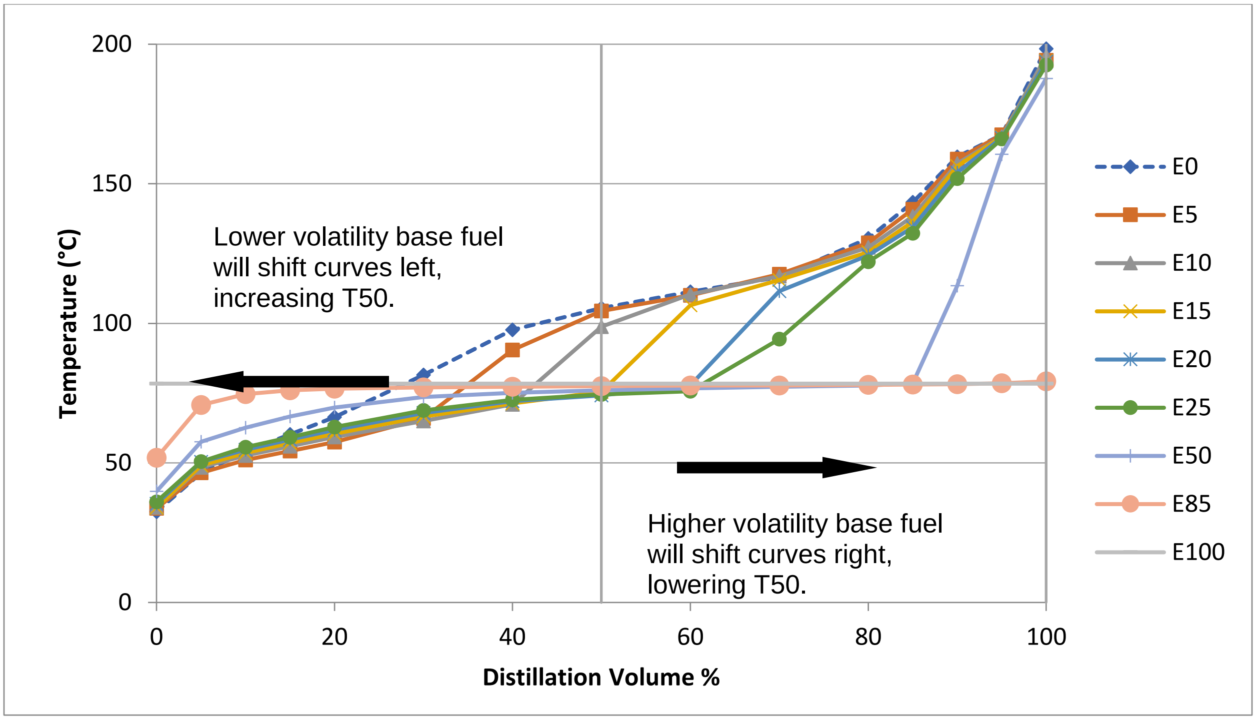



**FIGURE 7. DISTILLATION CURVES OF ETHANOL IN CERTIFICATION GASOLINE FROM ANDERSON (2010)[80]**

[80] V. F. Andersen, J. E. Anderson, T. J. Wallington, S. A. Mueller And O. J. Nielsen, Distillation Curves For Alcohol−Gasoline Blends, Energy Fuels, 2010, 24 (4), Pp 2683–2691.

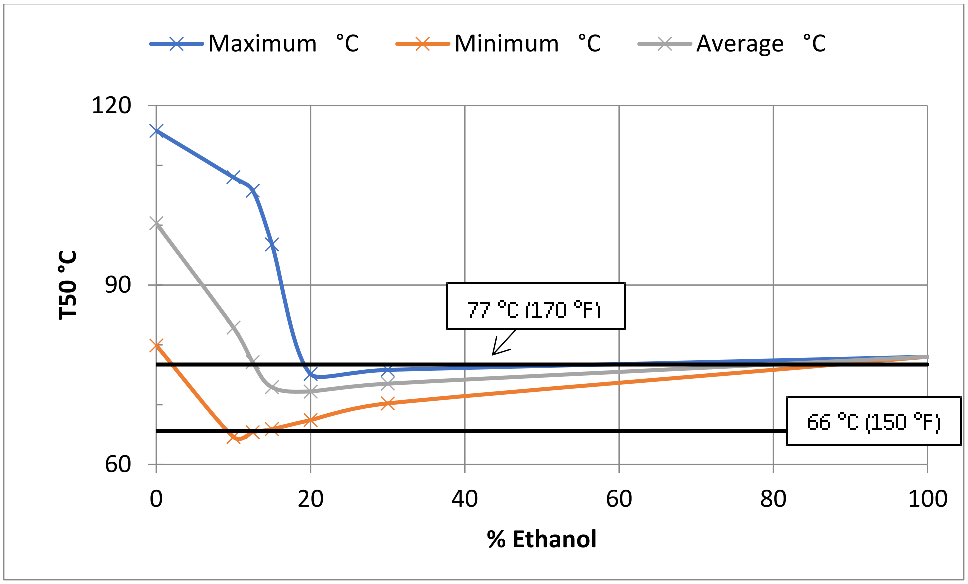



**FIGURE 8. T50 RANGE FOR A VARIETY OF GASOLINES AT VARIOUS ETHANOL CONCENTRATIONS**[81]

**TABLE 5. T50 FOR A VARIETY OF GASOLINES, INCLUDING SOME BOBS, BLENDED WITH BETWEEN 10% AND 30% ETHANOL, AND EXTRAPOLATED TO BOILING POINT OF ETHANOL.**[81]

| T50 °C (°F) | E0 (straight gasoline) | E10 | E12.5 | E15 | E20 | E30 | E100 (straight ethanol) |
|---|---|---|---|---|---|---|---|
| **Average °C** | 100.3 | 82.9 | 77.1 | 72.9 | 72.2 | 73.5 | 78 |
| **°F** | (212.6) | (181.2) | (170.8) | (163.2) | (161.9) | (164.3) | (173) |
| **Std. Dev. °C** | 7.6 | 14.7 | 11.2 | 5.4 | 1.6 | 1.0 | 0 |
| **°F** | (13.6) | (26.4) | (20.2) | (9.8) | (2.8) | (1.8) | (0) |
| **Minimum °C** | 79.9 | 64.6 | 65.4 | 65.9 | 67.4 | 70.2 | 78 |
| **°F** | (175.9) | (148.2) | (149.8) | (150.7) | (153.4) | (158.4) | (173) |
| **Maximum °C** | 115.8 | 108.0 | 105.8 | 96.8 | 75.1 | 75.8 | 78 |
| **°F** | (240.5) | (226.4) | (222.5) | (206.3) | (167.1) | (168.5) | (173) |

### 4.4 Additive Requirements for Gasoline-Ethanol Blends

The U.S. EPA and CARB (California Title 13, Chapter 5, Article 1 section 2257) require detergent additives to be added to gasoline to control deposit formation at a minimum dosing rate. The detergents are tested using ASTM D5598 and ASTM D5500 to ensure that they perform adequately. Detergent is generally considered necessary for the purposes of reducing fuel injector deposits from the hydrocarbon portion of the fuel. In approving blends up to E15, U.S. EPA concluded that no changes were required relative to levels required for use with E10.[82] Given this, and the available data described above, use of additive levels consistent with those that apply in California for E10 would also be appropriate for blends

[81]From data in American Petroleum Institute, Determination of the Potential Property Ranges of Mid-Level Ethanol Blends, Final Report, April 23, 2010 https://www.api.org/~/media/Files/Policy/Fuels-and-Renewables/2016-Oct-RFS/The-Truth-About-E15/E10-Blending-Study-Final-Report.pdf

[82] US Government Accountability Office, BIOFUELS Challenges to the Transportation, Sale, and Use of Intermediate Ethanol Blends, June 2011.

of up to at least E15. Testing would be required to determine the appropriate detergent treat rate for E20 and E30 fuels.

### 4.5 Vehicle Emissions

This section evaluates the available emissions test data to assess the impacts of ethanol blends in the E11 – E30 range on air quality. Impacts on greenhouse gas emissions (GHGs) are addressed in Section 8. Since only vehicles that have been built since model year (MY) 2001 are permitted to use E15 under EPA regulations (in addition to specially designed FFVs which are permitted to use any ethanol concentrations of up to 85%) only data from testing of these vehicles are considered here and impacts are assessed relative to E10.

#### *4.5.1 Test Fuels*

All blends of ethanol and gasoline up to E10 sold in California must comply with CARB's California Reformulated Gasoline (CaRFG) regulations. This requirement imposes limits on the allowable properties of petroleum blendstocks for oxygenate blending (CARBOBs) used in preparing these compliant blends. The analysis presented below is focused on assessing the emission impacts associated with use of gasoline-ethanol blends above E10 that are created via splash blending of ethanol into a CARBOB that complies with CARB regulations for E10. Because of the limited number of studies done comparing nominal E15 and E20 blends to E10, this review will also describe testing performed to compare E15 and E20 to E0. Inclusion of these studies is conservative given that any observed differences in emission between E15 and E20 relative to E0 should be larger than those expected to exist between E15 and E20 relative to E10.

Further, the analysis also uses data from some studies involving what is known as "match blending" instead of splash blending. In match blending, the properties of the CARBOB or other blendstock are intentionally altered such that the properties of the blends being compared, E10 and E15, for example, are as close as possible except for the difference in ethanol content. The match characteristics vary but frequently include vapor pressure, and/or aromatic content and/or T50. Splash blending, by contrast, employs the same base hydrocarbon fuel for each blend regardless of ethanol content. Studies which employ splash blending are more representative than match blending studies of the changes that would occur should E11-E30 fuels be blended with the same CARBOBs that are used for E10, as is proposed for these new fuels.

There are many issues that need to be considered when using data from match blending studies to evaluate impacts of splash blending. These include:

- match blending for multiple fuel properties is difficult and rarely perfectly successful, because it is impossible to change one property without changing many of the other properties;
- despite extensive study it is not clear which fuel properties are most important with respect to emissions because the effects of correlated properties cannot be easily separated from each other by statistical analysis; and
- there are numerous properties that could conceivably have an impact on emissions[83] such that no match blending study could control for changes in all properties that could impacts emissions.

Given the differences in match and splash blending, it is not surprising that there are differences in the results from studies using the two approaches to evaluate the impact of ethanol content on emissions.

[83] See for example, "Analysis of EPAct Emission Data Using T70 as an Additional Predictor of PM emissions from Tier 2 Gasoline Vehicles," (Darlington, T. et al. SAE 2016-01-0996).

Of the studies considered only one,[84] by Karavalakis and colleagues at UC Riverside, used a base or test fuel that was specifically described as "CARB" fuel. In that case, the base CARB fuel included 6.6% ethanol by volume and was diluted to create E10 and E20 blends while maintaining constant RVP, and the fuel was tested on only one 2001+ vehicle. In other work conducted at UC Riverside [85] the fuel was described as follows:

> "The ethanol fuels were blended …………to represent ethanol fuels that would be utilized in California, in terms of properties such as aromatic content, Reid vapor pressure (RVP), and other properties."

RVP and other fuel volatility parameters were matched within certain limits. A third study, also conducted by Karavalakis and his colleagues at the UC Riverside, did not employ
fuel that was selected based on compliance with CARB regulations and included both splash blended and match blended fuels.

### *4.5.2 Criteria Pollutants*

The criteria pollutants considered include nitrogen oxides, (NOx), carbon monoxide (CO), particulate matter (PM) and organic compounds. Organic compounds result from both combustion as well as fuel evaporation and can be characterized in a number of ways: total hydrocarbons (THC – which includes all hydrocarbons), non-methane hydrocarbons (NMHC - which includes all hydrocarbons except methane which is relatively non-reactive and thus not a significant predictor of ozone) or non-methane organic gases (NMOG – which include NMHC plus gases that may have an oxygen molecule, like ethanol, acetaldehyde or formaldehyde). In this document we report the organic emissions, in whatever form they were published in the relevant studies. The emissions data considered in this analysis are compiled in Appendix 2.

Emissions of organic compounds and NOx react in the atmosphere to form ozone, the primary component of smog in the presence of sunlight. Different organic molecules differ in their reactivity in the production of ozone. The total amount and composition of organic compounds emitted can be analyzed to provide a rough gauge of their ozone-forming potential. Thus studies which speciated or otherwise considered the reactivity of the specific organic compounds emitted during testing form a more reliable basis for assessing changes in the ozone- forming potential of changes in the ethanol content of blends.

### *4.5.3 Toxic Air Contaminants*

In assessing emissions of toxic air contaminants (TACs) from spark-ignition vehicles, U.S. EPA and CARB have long focused on emissions of formaldehyde, acetaldehyde,1,3-butadiene and benzene. Based on extensive research, the state of California has developed risk factors for exposure to these and other compounds.[86] These risk factors have been used by CARB to evaluate the relative toxic "potency" of the four compounds listed above for the purpose of assessing the relative risk in changes in fuel composition on overall exposure to air toxics. CARB's Predictive Model has assigned the weighting factors listed in Table 6 to these pollutants, based on their relative toxicity. The potency-weighted toxicity is calculated as the sum of the concentration of each of these pollutants times the weighting factor.

**TABLE 6. CARB TOXIC AIR CONTAMINANT POTENCY-WEIGHTING FACTORS**

| Pollutant | Weighting Factor |
|---|---|
| **Benzene** | 0.170 |
| **1,3-butadiene** | 1.000 |
| **formaldehyde** | 0.035 |
| **acetaldehyde** | 0.016 |

[84] Karavalakis, G., T. Durbin, M. Shrivasastava, Z. Zheng, M. Villela, H. Jung. "Impacts of ethanol fuel level on emissions of regulated and unregulated pollutants from a fleet of gasoline light-duty vehicles," *Fuel* 93 (2012) 549-558.
[85] Karavalakis, G., D. Short, D. Vu, R. Russell, A. Asa-Awuku, T. Durbin, "A Complete Assessment of the Emissions Performance of ethanol blends and Iso-Butanol blends from a fleet of Nine PFI and GDI Vehicles," SAE 2015-01-0957, (2015).
[86] CARB, California Procedures for Evaluating Alternative Specifications for Phase 3 Reformulated Gasoline Using the California Predictive Model, Last Amended August 24, 2012.

### 4.5.4 Statistical Analysis

Because test procedures were different, each dataset was analyzed independently. All emissions are presented on a weight/mile basis and were transformed logarithmically prior to the statistical analysis to equalize the impact of high and low emitting vehicles in determining the statistical significance of changes. Logarithmic transform of data is common with emissions data. Results were considered to be statistically significant for p<=0.05 and marginally significant if p fell between 0.05 and 0.1.

Extensive statistical analyses were also performed by the researchers and reported in these studies. In many cases the original researchers analyzed overall impacts between E0 and the highest ethanol blend considered, assuming linear effects. Where possible the statistical analysis performed here was limited to consider only emission differences between E10 and the higher gasoline-ethanol blends, given E10 as the reference point for this evaluation. Ethanol impacts on other fuel properties that are often thought to impact emissions (T50 and RVP) are clearly non-linear between E0, E10 and higher ethanol blends.

In addition, in the UC Riverside-3 study, the scientists apply the Tukey-Kramer correction to their analyses of the statistical significance of pairwise t test comparison of the eight different fuels they consider. This correction is intended to account for the increased probability of a Type 1 error (false positive showing statistically significant difference where none exists) when conducting multiple pairwise comparisons. For eight different fuels, and the resultant 28 different pairwise comparisons, this correction is quite large, resulting in p-values almost ten times the uncorrected value. However, this correction was not made in this statistical evaluation, since only four pairwise comparisons were made, with markedly less potential for false positives. Thus, in contrast to the original study report, the statistical analysis presented here found a marginally significant decrease in NOx emissions, and significant decrease in NMHC, as well as some significant changes in toxic emissions that were not identified in the original report. This type of finding also applies to differences in results presented here versus those presented in other original studies. Where statistical results differ, this is not due to errors in either analysis, but to differences in analytical approaches.

### 4.5.5 Tailpipe Emissions

The total dataset considered here includes tailpipe emissions from a total of 61 vehicles, including one FFV. Twenty-five vehicles were tested on E10 and E15; twenty-four were tested on E0 and E15; twenty-three were tested on E10 and E20; twenty-four were tested on E0 and E20 (there were a number of vehicles that fell into multiple categories). There are no published data on the impact of blends above E20 on tailpipe emissions. A summary of the results is included in Table 7 and Table 8 and a more detailed summary of the average emissions from each vehicle/test cycle/fuel are included in Appendix 2.

FFVs are vehicles designed and permitted to use any ethanol fuel level up to E85, but many may fill up with conventional fuel and so may be impacted by a change in the availability of E15 in place of E10. According to IHS Automotive[87] there are nearly 20 million FFVs on US roads today, or somewhere around one-tenth of the total number of vehicles on the road. Only one has been tested on E15 and E10, and the results of that test are included in this analysis.

Table 7 (E15) and Table 8 (E20) summarize the results of our analyses of the individual studies which directly compared the air emissions impacts of higher and lower ethanol concentrations in hydrocarbon fuel. None of the E15 studies, whether done on California fuels or other US fuels found a statistically significant increase in any criteria pollutant. NOx, CO, PM mass emissions, or organic emissions (NMOG, THC, or NMHC depending on the study) were measured. Statistically significant decreases were found for NMHC, CO and potency weighted toxics, and a marginally significant decrease in $NO_x$ emissions due to changes in ethanol content in the fuel.

[87] Cited by the US DOE, https://www.afdc.energy.gov/vehicles/flexible_fuel.html, accessed March 2, 2018.

For E20, organic emissions are reduced in several studies by a significant or marginally significant amount. A statistically significant reduction in CO is also found in one study and a marginally significant reduction in another study. A significant increase in NOx for E20 was found in a single study.

The results of the EPAct[88] study, a large EPA study of 15 vehicles and 27 fuels, is not explicitly included in this analysis because it does not provide emissions data for a set of lower and higher ethanol content fuels that are either match blended or splash blended, that could be analyzed in the manner we used for the other studies. The experimental design of the EPAct study included 27 different fuels, by blending for 5 specific properties in such a way that the full reasonable range of each property was explored, but not all the possible different combinations (which would have required 240 different fuels). EPA's analysis of the results of their emissions data suggest that the emissions of total hydrocarbon (THC), NMOG, NMHC, CH4, NOx, PM would increase, and CO would decrease with increasing ethanol content (between E0 and E20) should aromatic content, T50, T90 and vapor pressure be held constant. However, Section 4.3.4, shows that T50 is inversely correlated with ethanol content, as is aromatic content by simple dilution. Increasing aromatic content and T50 are also correlated with increasing THC, NMOG, NMHC, NOx, PM emissions, potentially confounding any increase in emissions due to ethanol alone.

### *4.5.6 Description of Studies*

#### *4.5.6.1 Coordinating Research Council Study E74-B*

The Coordinating Research Council (a consortium of car and petroleum companies) conducted a study[89] in 2009 which included 15 vehicles, model years 1994 to 2006, tested over the Federal Test Procedure (FTP) cycle. The study was intended to separate the effects of vapor pressure, ethanol content and test temperature on CO exhaust emissions, but THC and $NO_x$ emissions were also reported. Seven match blended[90] E0, E10 and E20 fuels were tested at several different vapor pressures. Because their study included vehicles older than the 2001 MY cutoff, and E0 fuels, the CRC statistical analysis is not considered directly applicable. Instead, for this analysis, the dataset has been limited to tests conducted on post 2001 MY vehicles, the E20 fuel and the only E10 fuel with the same vapor pressure.

The results showed that for vehicles using both E20 and E10, the higher ethanol content fuel yielded an increase in $NO_x$ in 6 out of the 11 vehicles at 75 °F, and for 7 out of 11 vehicles at 50 °F. The 2006 Ford Taurus seemed to show an especially large sensitivity to ethanol content in both tests. However, when the wide variability between vehicles is taken into account, the change in $NO_x$ is not statistically significant (p=0.38) and could be due to chance alone. Similarly, there was a decrease in THC emissions for E20 in 8 out of 11, and 6 out of 11 vehicles in the 75 °F and 50 °F tests respectively. For the 75 °F test, the difference between THC emissions using the two different fuels is statistically significant at the 95% level ($p <= 0.05$), but not for the 50 °F test. When the datasets at the two temperatures are combined, the reduction in THC is marginally significant (p=.051). Finally, for CO, 6 of the 11 vehicles saw a decrease at 75 °F, 7 out of 11 saw a decrease at 50 °F, but, statistically, this difference was not significant at either temperature.

Overall, there is little apparent difference in emissions between E10 and E20 from later model vehicles (2001+) for these criteria pollutants; given that differences between E10 and E15 should be smaller, the impact of changing from E10 to E15 would likely not cause any increase in emissions in these vehicles.

#### *4.5.6.2 The Department of Energy (DOE) Study of Intermediate Blends on Legacy Vehicles*

This study[91] included a number of vehicles older than 2001 and therefore the statistical analysis which accompanied the study is not applicable. Instead the data from the 2001+ MY vehicles were extracted

---

[88] EPA, Assessing the Effect of Five Gasoline properties on Exhaust Emissions from Light-Duty Vehicles Certified to Tier 2 Standards: Analysis of Data from EPAct Phase 3 (EPAct/V2/E-89), Final Report, April 26, 2013. https://www.epa.gov/moves/epactv2e-89-tier-2-gasoline-fuel-effects-study, accessed September 23, 2018.

[89] CRC E74-B, Effects of Vapor Pressure, Oxygen Content and Temperature on CO Exhaust emissions, May 2009.

[90] The fuels were blended to match four distillation points, octane values, and aromatic, benzene, olefin and sulfur content as close as practicable. For the E20 fuel, especially, a tight match was not possible.

[91] Knoll,K., B. West, W. Clark, R. Graves, J.Orban, S. Przesmitzki, T. Theiss , Effects of Intermediate Ethanol Blends on Legacy Vehicles and Small Non-Road Engines, Report 1 – Updated February 2009, NREL/TP-540-43543.

and analyzed. The base hydrocarbon fuel used was certification gasoline, and ethanol was fuel-grade per ASTM D4806. In this case we were able to compare splash-blended E15 with E10 and found $NO_x$ increased in 7 out of 13 of 2001+ MY vehicles, and NMHC and CO decreased in 7 out of 13 vehicles, and 8 out of 13 vehicles, respectively. In comparison to the variability between the vehicles, the paired t-test conducted for each of these pollutants finds that the difference between the E15 results and the E10 results is not significant.

The same vehicles were tested on splash-blended E20. These showed a large (30%) and statistically significant increase in NOx (11 out of 13 vehicles), a marginally significant decrease of -5% in NMHC (9 out of 13 vehicles) and no statistically significant impact on CO emissions.

*4.5.6.3 DOE Catalyst Study*

The purpose of this study[92] was to determine if the use of higher ethanol content fuels for the full useful life of a vehicle (as defined in the EPA emissions standards) would adversely affect the emissions control systems and result in emissions which exceeded the EPA emissions standards. Retail top-tier E0 fuel was splash blended with ASTM D4806 ethanol to produce E10, E15 and E20 blends. This was the largest study and included 24 matched (make, model and approximate starting mileage) sets of vehicles which accumulated mileage on E0, E10, E15 or E20 and then were tested on different ethanol fuels. The vehicles aged on E15 were tested on E15 and E0, and the vehicles aged on E20 were tested on E0 and E20. No vehicle sets were tested on both E10 and E15, or E10 and E20 in this program.

Average emissions in the DOE Catalyst study show significant reductions in CO between E15 and E0 (-13%), and changes which are not statistically significant in NMOG and $NO_x$. The same make and model vehicles tested on E20 versus E0 showed no statistically significant change in NOx, and large significant reductions in NMOG (-16%) and CO (-22%). It is not clear how much of the difference between E0 and E15 occurs between E0 and E10 and what is due to the change between E10 and E15, or E10 and E20. However, the implication of this study is that changes in NOx emissions are likely to be non-detectable in these vehicles, and there is an apparent reduction in CO and NMOG.

*4.5.6.4 UC Riverside-1 and UC Riverside-2*

A total of 7 standard vehicles and one FFV MY 2001+, were tested by Karavalakis and his colleagues at UC Riverside using E10, E15 and E20 fuels that would likely be permissible in California should the higher ethanol fuels be legalized. Those results were reported in three different papers[93], and an extensive statistical analysis of the results from seven of those vehicles was made in a 2015 SAE paper. In addition, a single FFV, a 2007 Chevrolet Silverado, will be considered independently of the other vehicles because it is a different type of vehicle and also because it was not tested on E15 but was tested on E20 and E10. The data was provided in graphical form in the published papers, but this analysis of the 7 standard vehicles was based on the data in Excel form provided to us courtesy of Dr. Karavalakis. The graphic presentation of the Chevrolet Silverado results was on such a small scale that magnitude could not be accurately gauged and only the direction of change can be reported.

Considering only both E20, E15 and E10 emissions from the seven vehicles, Karavalakis and his colleagues found there were no significant differences in the weighted (cold start and running) emissions for PM, THC, NMHC, CO and $NO_x$ emissions, although the cold start emissions were slightly higher for both THC and NMHC for E15, and the difference was statistically significant. They did not report any significant changes in PM mass and total particle number, between E15 and E10. Our analysis, in Table 7 generally supports these conclusions, although we found a marginally significant decrease in CO between E20 and E10. In addition, we calculated potency-weighted toxicity for the 7 vehicles and found

[92] West, B.H., C. S. Sluder, K.E. Knoll, J.E. Orban, J. Feng, Intermediate Ethanol Blends Catalyst Durability Program, February 2012, ORNL/TM-2011/234.

[93] Karavalakis, G., D. Short, D. Vu, R. Russell, A. Asa-Awuku, T. Durbin, " Evaluating the regulated emissions, air toxics, ultrafine particles, and black carbon from SI-PFI and si-di vehicles operating on different ethanol and iso-butanol blends," *Fuel* 128 (2014), 410-421.

no significant difference between these pollutants at either E15 or E20 and E10. The study also reported extensively on other pollutants including methane, carbon dioxide and a number of individual VOCs.

The single FFV (MY 2007) showed small reductions in all pollutants including CO, THC, NMHC and $NO_x$ for E20 in comparison to E10, although none appear statistically significant in comparison to the standard deviations of the measurements as shown on the graph. Tests on higher ethanol concentrations suggest the trend is for reductions in CO, THC and NMHC at E20 and higher ethanol concentrations for this FFV. Taken together these CARB fuel studies show no evidence for any increase in emissions for potency-weighted toxicity, PM, CO, THC, NMHC or $NO_x$ if E15 or E20 replaces E10 fuel in California.
The UC Riverside team performed this analysis for emissions from two 2012 model year vehicles and found that the ozone reactivity for emissions from E15 was less than those for E10 as shown in the figure below.

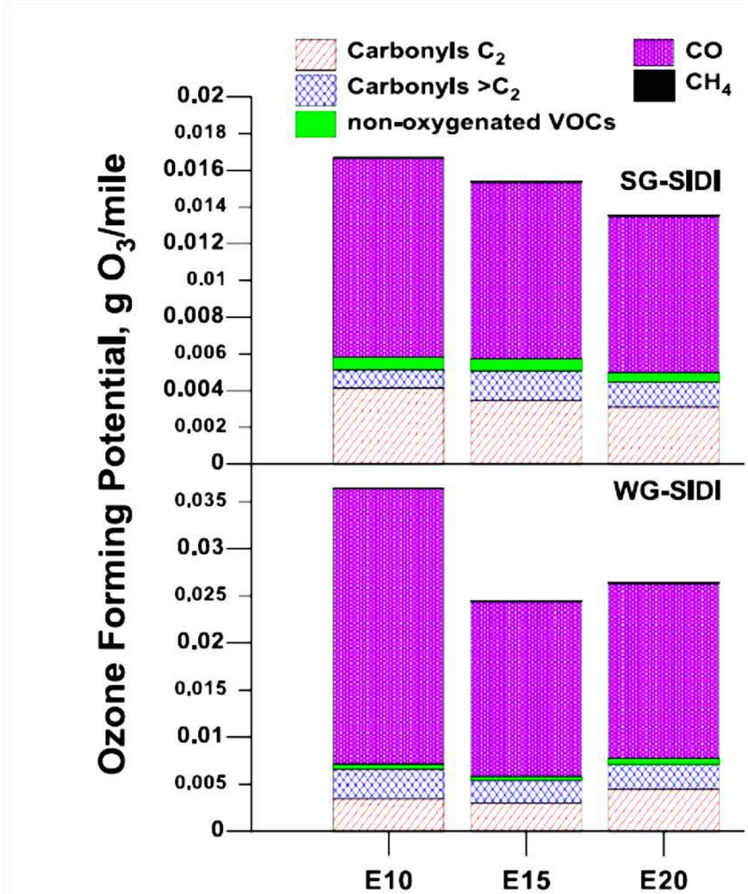



**FIGURE 9. OZONE-FORMING POTENTIAL OF TAILPIPE EMISSIONS FROM VEHICLES USING E10, E15 AND E20.[94]**

Because of the extremely limited data on the ozone-forming potential of E15 versus E10 the impact of both higher and lower ethanol contents on ozone-forming potential will be briefly mentioned, although this may not be representative of the change between E15 and E10. In their extensive study of FFV vehicle emissions from E6, E32, E59 and E85 fuels the CRC[95] found that the average ozone-forming potential

[94] Karavalakis, G., D. Short, D. Vu, R. Russell, A. Asa-Awuku, H. Jung, K.C. Johnson, T. Durbin, "The impact of ethanol and iso-butanol blends on gaseous and particulate emissions from two passenger cars equipped with spray-guided and wall-guided direct injection SI (spark ignition) engines," *Energy* 82 (2015) 168-179.
[95] CRC E-80, Exhaust and Evaporative Emissions Testing of Flexible-Fuel Vehicles, Final Report, August 2011.

decreased with increasing ethanol content of the fuels on the cold start FTP. There were mixed results on the US06 and Unified Cycle tests. Wang and colleagues[96] in China found a slight improvement in ozone-forming potential calculated from MIR values when E10 was compared to E0 in a Euro 4 vehicle. Taken together, these results suggest that there will be no increase in ozone-forming potential with higher ethanol content fuel.

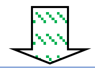
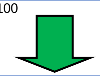
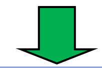
#### *4.5.6.5 UC Riverside-3*

In another study conducted by UC Riverside[97] five 2016 and 2017 MY vehicles were tested on match-blended (E0, E10 and E15, at both high and low aromatic content) and splash-blended (E10, E15 and E20) fuels. The results of the study found that the splash blended E15 caused significant reduction in NMHC, THC and potency weighted-toxics, and marginally significant reductions in NOx. However, these reductions were not found in the splash blended E20 when compared to E10. The vehicles tested with match blended E10 and E15 showed no statistically significant differences at either low or high aromatic content.

In addition, the tailpipe emissions from one vehicle tested on the eight different fuels was injected into an atmospheric chamber to determine the potential for these emissions to form secondary aerosols in the environment. Secondary aerosol formation showed a weak negative correlation with increased ethanol content from E0 to E20, suggesting that higher concentrations of ethanol in fuel will lead to less secondary aerosols.

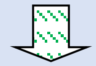
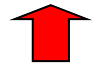
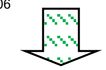
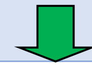
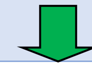
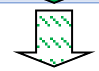
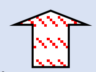
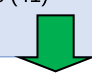
[96] Wang, X, Y. ge, C. Zhang, J. Liu, Z. Peng, H. Gong., Estimating Ozone Potential of Pipe-out Emissions from euro-3 to euro-5 Passenger cars Fueled with gasoline, Alcohol-Gasoline, Methanol and Compressed Natural Gas, SAE 2010-01-1009.
[97] Karavalakis, G, T.D. Durbin, J. Yang, P. Roth, Impacts of Aromatics and Ethanol Content on Exhaust Emissions from Gasoline Direct Injection (GDI) Vehicles, April 2018.

**TABLE 7. TAILPIPE EMISSIONS STUDIES ON E15 VERSUS EITHER E10 OR E0 AS BASE FUEL[98]**

| Study Name | Test Cycle | No. of Vehicles | Vehicle Model Years | Base Fuel and Blending Strategy | $NO_x$ | Organic Emissions | CO | PM mass emissions | Potency Weighted Toxics[99] |
|---|---|---|---|---|---|---|---|---|---|
| **DOE Intermediate Fuel Blends** | LA-92 | 13 | 2001-2007 | E10 splash blend | No significant difference | No significant difference[100] | No significant difference | Not tested | Not tested |
| **DOE Catalyst Study** | FTP | 24 | 2003-2009 | E0 splash blend | No significant difference | No significant difference[101] |  | Not tested | Not tested |
| **UC Riverside -1** | UC and FTP | 7 | 2007-2012 | E10 match blend | No significant difference | No significant difference[102] | No significant difference | No significant difference | No significant difference |
| **UC Riverside -3** | LA-92 | 5 | 2016-2017 | E10 low aromatics splash |  | [100]  | No significant difference | No significant difference |  |
| **UC Riverside -3** | LA-92 | 5 | 2016-2017 | E10 low aromatics match blend | No significant difference | No significant difference[100] | No significant difference | No significant difference | No significant difference |
| **UC- Riverside-3** | LA-92 | 5 | 2016-2017 | E10 high aromatics match blend | No significant difference | No significant difference[100] | No significant difference | No significant difference | No significant difference |
| **All Data (no. of datapoints for each pollutant in parentheses)** | Various | | 2001-2017 | Various | No significant difference (66) | NMHC:No significant difference (42) THC:No significant difference (29) NMOG:No significant difference (24) |  (66) | No significant difference (24 ) | No significant difference (22 ) |

[98] Solid arrows represent p values <.05, textured arrows represent p values between 0.05 and 0.1, for paired, two-tailed t-test.
[99] Calculated using CARB factors in California Procedures for Evaluating Alternative Specification for Phase 3 Reformulated Gasoline Using the California Predictive Model, Last Amended August 24, 2012
[100] Non-methane hydrocarbons, NMHC
[101] Non-methane organic gases, NMOG
[102] Total hydrocarbon and non-methane organic gases, THC and NMHC both measured with same statistical conclusion

**TABLE 8. TAILPIPE EMISSION STUDIES ON E20 EITHER E10 OR E0 AS BASE FUEL[103]**

| Study Name | Test Cycle | No. of Vehicles | Vehicle Model Years | Fuels | $NO_x$ | Organic Emissions | CO | PM mass emissions | Potency Weighted Toxics[104] |
|---|---|---|---|---|---|---|---|---|---|
| **CRC E74B** | FTP | 11 (at two different temps) | 2001-2006 | E10 match blend | No significant difference | [105]  | No significant difference | Not tested | Not tested |
| **DOE Intermediate Fuel Blends** | LA-92 | 13 | 2001-2007 | E10 splash blend |  | [106]  | No significant difference | Not tested | Not tested |
| **DOE Catalyst Study** | FTP | 24 | 2003-2009 | E0 splash blend | No significant difference | [107]  |  | Not tested | Not tested |
| **UC Riverside-1** | UC and FTP | 7 | 2007-2012 | E10 match blend | No significant difference | No significant difference[108] |  | No significant difference | No significant difference |
| **UC Riverside-2** | FTP | 1 FFV | 2007 | E10 match blend | E20 emissions less than E10 | E20 emissions less than E10[106] | E20 emissions less than E10 | Not tested | Reported on graph, E20 is slightly less than E10 |
| **UC Riverside -3** | LA-92 | 5 | 2016-2017 | E10 low aromatics splash | No significant difference | No significant difference[106] | No significant difference | No significant difference | No significant difference |
| **All Data (no. of datapoints for each pollutant in parentheses)** | Various | | 2001-2017 | Various |  (77) | NMHC: No significant difference (32) THC: No significant difference (41) NMOG: (24)  |  (78) | No significant difference (15) | No significant difference (12) |

[103] Solid arrows represent p values <.05, textured arrows represent p values between 0.05 and 0.1, for paired, two-tailed t-test.
[104] Calculated using CARB factors in California Procedures for Evaluating Alternative Specification for Phase 3 Reformulated Gasoline Using the California Predictive Model, Last Amended August 24, 2012
[105] Total hydrocarbon, THC
[106] Non-methane hydrocarbons, NMHC
[107] Non-methane organic gases, NMOG
[108] Total hydrocarbon and non-methane organic gases, THC and NMHC both measured with same statistical conclusion

#### 4.5.7 Evaporative Emissions

Evaporative emissions are volatile organic compounds which escape from the fuel system of the vehicle. Fuel systems are designed to be sealed off from the atmosphere, although emissions can occur due to system liquid leaks, vapor leaks through the air emissions control system and permeation of vapors through the materials that make up the fuel lines and other components of the fuel system.

Liquid leaks are rare but can result in large quantities of emissions. They are due to poorly maintained vehicles, or carelessness when fueling. The composition of the fuel is not believed to have any impact on the amount of liquid leaks.

Because this study is intended to evaluate E11-E30 generated from the blending of fuels into the same CARBOBs used for E10, California E10, E15 and E20 fuels would be expected to have roughly identical vapor pressures. (In many areas of the country E10 is permitted to have a vapor pressure that is 1 psi higher than either E0 or E15 fuel, but it is not expected to be permitted in California). E30 would slightly reduce the vapor pressure.

The quantity of evaporative emissions vented to the emissions control system, and the amount which escapes would be expected to be roughly the same for fuels with the same vapor pressure, thus we do not expect any differences due to splash blended E15 or E20 versus E10. E30 fuels would likely decrease these emissions by a small amount proportional to the reduction in vapor pressure. However, permeation emissions, in which fuels move through the fuel system materials are chemical specific and could be different for fuels with different chemical compositions. Two Coordinating Research Council studies were conducted to determine if higher ethanol content would affect permeation emissions.

Evaporative emissions of benzene are also of concern, but it should be noted that the other TACs of concern besides benzene are only of concern with respect to exhaust emissions. Unfortunately, no measurement of benzene emissions were reported in either of these two studies of E20 evaporative emissions. It seems likely that since benzene comes from the hydrocarbon portion of the ethanol-gasoline blend, diluting the hydrocarbon portion with additional ethanol would likely decrease the amount of benzene emissions by a roughly proportional amount.

**TABLE 9. EVAPORATIVE EMISSION STUDIES ON E20**

| Study Name | Test Cycle | No. of Vehicles | Vehicle Model Years | Fuels | Organic Emissions | Ozone forming potential |
|---|---|---|---|---|---|---|
| **CRC E-65-3** | Diurnal | 4 | 2001-2005 | E10 match blend | No significant difference | No significant difference |
| **CRC E-65-3** | Steady-state | 4 | 2001-2005 | E10 match blend | No significant difference | No significant difference |
| **CRC E-77-2** | Static | 6 | 2001-2006 | E10 match blend | No significant difference | Not tested |
| **CRC E-77-2** | Running Loss | 6 | 2001-2006 | E10 match blend | No significant difference | Not tested |
| **CRC E-77-2** | Hot Soak | 6 | 2001-2006 | E10 match blend | No significant difference | Not tested |
| **CRC E-77-2** | Diurnal (3-day) | 6 | 2001-2006 | E10 match blend | No significant difference | Not tested |

*4.5.7.1 Description of Studies*

4.5.7.1.1 Coordinating Research Council Study E-65-3

CRC E-65-3[109] was conducted using a number of fuels (E0, E6, E6 high aromatics, E10, E20 and E85), and five vehicles, but only the results of E10 and E20 (matched aromatic content) conducted on the four post 2001 MY vehicles are considered here. Neither E15 nor E30 were tested. The fuel systems were removed from the vehicles and the fuel rigs were tested over the 24-hour diurnal test in a Variable Temperature Sealed Housing Evaporative Determination (VT-SHED) using the California Enhanced Evaporative Testing rules. The fuel tanks and the canisters were vented to the outside of the SHED to limit measured emissions to permeation emissions alone. Test results in mg/day for the four vehicles are shown in Table 3 of the study. Two of the vehicles showed increases comparing E20 to E10, and two showed decreases, and the net change is not considered statistically significant. The specific reactivity of the emissions was measured and the ozone-forming potential was calculated. The result, in Table A- 8 of the study, shows that the ozone-forming potential of the permeation emissions from the two fuels were not statistically distinguishable.

4.5.7.1.2 Coordinating Research Council Study E-77-2

Similar permeation testing was conducted by Coordinating Research Council[110] in 2010 on six vehicles that were 2001+ MY. Again, the testing was conducted in a SHED to capture permeation emissions, with all of the emissions from the vehicle's activated carbon canister vented to the outside. The vehicles were tested on two E10 fuels, with vapor pressures of 7 psi and 10 psi, and a single match-blended E20 fuel (aromatic content held constant between the fuels) with a nominal vapor pressure of 9 psi, but which actually had a vapor pressure of 8.5 psi. The 10 psi E10 fuel was created from the 7 psi E10 fuel by adding butane. In order to equalize any impact of vapor pressure, the emissions results of the two E10 fuels were averaged to roughly estimate the emissions of an 8.5 psi fuel.

Measurements were made for the following tests:

- Static permeation: fuel system pressurized and monitored for vapor and fuel leaks at 86 °F
- Running loss: two cycles of the LA-92 test at 86 °F

[109] CRC E65-3 Fuel Permeation from Automotive Systems: E0, E6, E10, E20 AND E85, Final Report, December 2006.
[110] CRC E77-2 Enhanced Evaporative Emission Vehicles, March 2010.

- Hot soak: one hour immediately following LA-92 test
- Diurnal test: California 3-day test, in which temperature is varied between 65 °F and 105 °F.

None of the tests resulted in a statistically significant difference between the average of the E10 7 and 10 psi fuel results and the E20 8.5 psi fuel. Two of the tests showed an average increase in the higher ethanol content fuel, one showed almost no change, and one found a decrease.

Taken together, these results suggest that there is no trend in permeation emissions between E10 and E20 in these studies. There is no data specific to permeation emissions from E15 fuel, but these results suggest that they will not be significantly different than E10 emissions. There is no information on the impact of E30 on permeation emissions. A 2007 study[111] showed that permeation was strongly linked to aromatic content, with a 35% increase in permeation with every 10% increase in fuel aromatic content. Adding ethanol to the E10 in current use in California, as is proposed in this multimedia analysis, would decrease the aromatic concentration a small amount, and thus also potentially decrease the permeation emissions to a small extent.

#### *4.5.8 Combined Analysis of All Emissions Data*

Taken independently, these studies show no consistent, measurable difference between E10 and E15 or E10 and E20 tailpipe emissions of $NO_x$, organics, PM or toxic weighted potency, although a number of studies showed a tendency of lowered CO and organic emissions with both E15 and E20, and one study showed a statistically significant increase in NOx emissions with E20. Combining the data from all of the studies (Table 6 in Appendix 2) shows a statistically significant decrease in CO with both E15 (-7%, p value = 0.0009), and E20 (-9%, p value =0.0002), and a marginally significant increase (+11%, p value = 0.07) in NOx with E20. There is limited evidence that the organics emitted from the tailpipe will have a lower ozone forming potential with E15 in comparison to E10 for both California-specific fuels and other test fuels in the US and China.

The total mass of permeation emissions and the ozone-forming potential of those emissions from E20 and E10 are statistically indistinguishable, suggesting that the use of E15 or E20 in place of E10 will have no impact on permeation emissions. There has been no reported testing on benzene evaporative emissions. It seems likely that benzene emissions would decrease at higher ethanol content, since benzene is only present in the hydrocarbon portion of ethanol-gasoline blends.

These results are supported by tailpipe emissions data from 61 vehicles and permeation emissions data from 10 vehicles. There have been no emissions testing of 2001+ MY vehicles with E30.

### 4.6 Summary of Findings

The extensive existing emissions data shows that use of gasoline blends up to E15 as allowed by U.S. EPA in existing 2001 and later model-year vehicles and FFVs will not result in any increase in vehicle exhaust emissions of organic compounds or their ozone-forming potential, oxides of nitrogen, carbon monoxide, particulate matter, or potency-weighted toxic air contaminants relative to E10.

[111] Reddy, S. Understanding Fuel Effects on Hydrocarbon Permeation through Vehicle Fuel System Materials, SAE 2007-01-4089.

**Growth Energy Comments on "Biofuels and the Environment: Third Triennial Report to Congress (External Review Draft)"**

Docket ID No. EPA–HQ–ORD–2020–0682

# Exhibit 4

**Environmental Health & Engineering, Inc.**
180 Wells Avenue, Suite 200
Newton, MA 02459-3328
TEL 800-825-5343
781-247-4300
FAX 781-247-4305
www.eheinc.com

February 10, 2023

U.S. Environmental Protection Agency
1200 Pennsylvania Avenue NW
Washington, DC 20460

Docket Number: EPA-HQ-OAR-2021-0427

Comments of David MacIntosh[1,2], Tania Alarcon[1,3], Brittany Schwartz[1], Fatemeh Kazemiparkouhi,[1] and Helen Suh[3]
[1] Environmental Health & Engineering, Inc., Newton MA
[2] Harvard T.H. Chan School of Public Health, Boston, MA
[3] Tufts University, Boston, MA

**RE: Response to Proposed Renewable Fuel Standard (RFS) Program Standards for 2023–2025**

## INTRODUCTION

We at Environmental Health & Engineering (EH&E) are a multi-disciplinary team of environmental health scientists and engineers with expertise in measurements, models, data science, lifecycle analyses (LCA), and public health. Members of our team conducted a state of the science review of the carbon intensity (CI) for corn ethanol in the United States (U.S.), as well as a reply supporting our work[1,2] and a comprehensive assessment of the impacts of corn ethanol fuel blends on tailpipe emissions.[3,4] A primary conclusion from our past and present work is that the best available science suggests a well-to-wheel corn starch ethanol CI of 51 $gCO_2e/MJ$, representing an approximately 46% reduction in GHG emissions relative to the petroleum gasoline baseline.[5] Over the past several months, we have submitted public comments

[1] Scully, M.J., Norris, G.A., Alarcon Falconi, T.M., and MacIntosh, D.L. 2021a. Carbon intensity of corn ethanol in the United States: state of the science. Environmental Research Letters, 16(4), pp.043001.
[2] Scully, M.J., Norris, G.A., Alarcon Falconi, TM., and MacIntosh, D.L., 2021. Reply to Comment on 'Carbon intensity of corn ethanol in the United States: state of the science'. Environmental Research Letters, 16(11), p.118002.
[3] Kazemiparkouhi, F., Alarcon Falconi, T.M., Macintosh, D.L., and Clark, N. 2022a. Comprehensive US database and model for ethanol blend effects on regulated tailpipe emissions. Sci Total Environ, 812, pp.151426.
[4] Kazemiparkouhi, F., Karavalakis, G., Alarcon Falconi, T.M., Macintosh, D.L., and Clark, N. 2022b. Comprehensive US database and model for ethanol blend effects on air toxics, particle number, and black carbon tailpipe emissions. Atmospheric Environment: X, 16, 100185.
[5] Scully et al. 2021a.

to governmental agencies including EPA and the State of Washington.[6,7,8,9,10] We have also recently published a reply that shares feedback on a recent but questionable study of domestic land use change.[11] A theme present across all of our analyses is that, overall, the CI estimates for the indirect land use change (iLUC) associated with corn starch ethanol have been converging on lower values when considering the best available science and improved models. The latest analyses of the four commonly relied upon models—GTAP-BIO, FAPRI-CARD, MIRAGE, and GLOBIOM—show results that are 2-fold to 4-fold lower than the results from studies that use outdated models. Studies that do not incorporate the best available science suggest a strong link between biofuel expansion and iLUC; as we will discuss, recent empirical research does not support that relationship.

While we can gain preliminary insight from the convergent downward trend of recent studies with updated models, this is not to say that the estimates from all updated models and analyses should be weighted equally. In this letter, we provide an example of a process that EPA may consider to evaluate studies against a set of criteria and assign more weight to studies that reflect the best available science. In our Scully et al. 2021 analysis, we critically evaluated models and input data used in 26 CI land use change (LUC) values published from 2008 to 2020.[12] Our evaluation process is outlined in detail in the paper and within a supplemental table. Based on the best available science, we determined a credible range for LUC of -1.0 to 8.7 gCO2e/MJ with a central best estimate of 3.9 gCO2e/MJ. We continue to view that range and the central best estimate as credible based on best available science.

We submit this letter to EPA in response to the proposed Renewable Fuel Standard (RFS) Program: Standards for 2023–2025 and Other Changes (hereafter, "the Set Proposal")[13] and the associated Draft Regulatory Impact Analysis (DRIA)[14].

---

[6] EH&E. 2022a. Comments on the 2022 Workshop on Biofuel Greenhouse Gas Modeling. 1 April 2022. Available within POET's comment at: https://www.regulations.gov/comment/EPA-HQ-OAR-2021-0921-0047

[7] EH&E. 2022b. Climate Response to 2020, 2021, and 2022 Renewable Fuel Standard (RFS) Proposed Volume Standards. 3 February 2022.

[8] EH&E. 2022c. Comments on the New York State Climate Action Council Draft Scoping Plan. 1 July 2022.

[9] EH&E. 2022d. Comments on the draft Washington Clean Fuels Program Rule (Chapter 173-424 WAC). 25 April 2022.

[10] EH&E. 2022e. Comments on the Washington Clean Fuels Program Rule (Chapter 173-424 WAC). 31 August 2022.

[11] Alarcon Falconi, T.M., Kazemiparkouhi, F., Schwartz, B., and MacIntosh, D.L. 2022. Inconsistencies in domestic land use change study. Proceedings of the National Academy of Sciences, 119(51), p.e2213961119.

[12] Scully et al. 2021a.

[13] EPA. 2022a. Proposed Renewable Fuel Standard (RFS) Program: Standards for 2023–2025 and Other Changes. December 2022. EPA-HQ-OAR-2021-0427.

[14] EPA. 2022b. Draft Regulatory Impact Analysis (DRIA): RFS Standards for 2023-2025 and Other Changes. November 2022. EPA-420-D-22-003.

We write these comments in reply to EPA's invitation for comment at the end of section IV A of the Set Proposal (Federal Register page 80611). In addition to responding directly to the topics outlined by EPA, we present our perspectives on the downward trend of iLUC estimates as models have evolved to incorporate updated data and also look toward future implications. In looking forward, we summarize potential air quality and public health benefits associated with increased ethanol volumes.

To present these layers, we organize our report into three parts:

### *Part I: Discussion of iLUC Model Agreement for Corn Starch Ethanol*

In the first section of this letter, we use our familiarity with LCA literature to further review and comment on the downward trend observed within estimates of the iLUC of corn starch ethanol. We begin with this theme because of the focus on iLUC during the Biofuel Workshop[15] and within the DRIA, plus the analysis we present provides background information useful to our responses to EPA. The trends observed in our investigation here are consistent with our past findings.

First, we provide a brief introduction to how researchers estimate the carbon intensity of biofuels, noting that iLUC is a large proportion of many older estimates. We then frame the basics of iLUC modeling and mention some of the assumptions and inputs that can be adjusted or selected by modelers.

We next demonstrate that refined iLUC modeling estimates are reliably producing results of similar magnitude, which are materially lower than the results of older, unrefined models. We share five examples that follow the trend of low iLUC estimates after adjustments to models. The results from these studies are of similar size despite being the product of models with different methods, designs, data, parameter values, and adjustments.

After confirming that recent models are reliably generating similar results, we address the uncertainty that surrounds iLUC estimates. We also review empirical observations to reveal that real-world data may not link biofuel production and LUC, supporting the lower iLUC estimates generated by refined and current models. Both of these considerations encourage the use of improved models to reduce uncertainty and tune results to observed land use statistics and trends.

Our findings further make the case that, across the board, corn starch ethanol iLUC estimates that rely on improved models of the four commonly relied upon models—GTAP-BIO, FAPRI-

---

[15] EPA. 2022c. Workshop on Biofuel Greenhouse Gas Modeling. https://www.epa.gov/renewable-fuel-standard-program/workshop-biofuel-greenhouse-gas-modeling

CARD, MIRAGE, and GLOBIOM— are trending downward and are 2-fold to 4-fold lower than older results from EPA 2010 and California Air Resources Board (CARB) in 2015/2018. Model adjustments and data improvements, which tune results closer to reality, are responsible for the downward trend, which is observed even when different models and different adjustments are studied.

### *Part II: Response to EPA's Invitation for Comment*

Our letter then directly replies to EPA's invitation for comment. We first commend EPA for using the approach of a literature review in order to make decisions without delay, based on the current state of the science. We also compare the range of results with the ranges identified in our Scully et al. 2021 paper.

We then look closely at the studies included in EPA's literature review. As the studies vary in quality, we recommend EPA define and apply criteria to assess the quality of each study and down-weight studies that are not as reliable. We propose an example of conditions EPA can use to determine which studies are most suitable for producing results that inform policy.

We then comment on how EPA should consider impacts over time, in terms of both adjustments of model results and looking toward the future. We also provide considerations for EPA around new research that is now available.

### *Part III: Additional Air Quality Benefits of Corn Starch Ethanol*

To close the letter, we shift our discussion from carbon to other emissions and discuss ethanol's role in mitigating health effects from vehicle fuel use. In doing so, we review the best available science on the connection between ethanol, emissions, air quality, and health.

Our review of the literature and results from our emission studies demonstrate benefits of higher ethanol fuel blends. We first show that as the percentage of ethanol blended with gasoline increases, the content of aromatics (hazardous air pollutants) in the fuel decrease. Next, we explain that, to the extent that ethanol is a substitute for aromatics in fuel, higher ethanol fuel blends reduce particle matter (PM), benzene, toluene, ethylbenzene, m/p-xylene and o-xylene (BTEX), 1-3 butadiene, black carbon (BC), and particle number (PN) emissions with no concomitant increase in carbon monoxide (CO), total hydrocarbons (THC), oxides of nitrogen (NOx), or acrolein emissions. Although ethanol fuel blends have higher acetaldehyde and potentially formaldehyde emissions than non-ethanol fuels, atmospheric measurements indicate that use of ethanol blends do not increase concentrations of acetaldehyde and formaldehyde above background levels in ambient air, indicating that emissions from other sources are larger than from light-duty vehicles.

We then summarize the findings of numerous studies that have shown that lower PM emissions result in lower ambient PM concentrations and exposures, which in turn are causally associated with lower risks of total mortality and cardiovascular effects. As cardiovascular disease is a leading mortality cause in the U.S., higher ethanol fuel blends offer a valuable opportunity to reduce PM concentrations and risk of adverse cardiovascular and respiratory outcomes (section 5). Higher ethanol fuel blends would also likely reduce benzene concentrations (an aromatic) and the associated cancer risk, since 40% of benzene emissions are attributed to the transportation sector and higher ethanol fuel content has lower aromatic emissions.

We also consider the disproportionate impact of air pollution on environmental justice communities (EJCs). EJCs are more likely to be situated near dense traffic corridors and may be exposed to higher concentrations of pollutants, in particular PM. An increase in the ethanol content of fuels can decrease EJCs' exposure to PM and the associated adverse health impacts. In closing this section, we present a brief case study for New York City.

## PART I: DISCUSSION OF ILUC MODEL AGREEMENT FOR CORN STARCH ETHANOL

In Part I, we first share examples of refinements to modeling estimates for iLUC. These results show that studies that include model improvements tend to be 2-fold to 4-fold lower than the earlier estimates from EPA and CARB, even when studies rely on a variety of models. We then review empirical statistics that dispel the link that some older, unrefined models make between U.S. biofuel production and iLUC.

### ESTIMATING THE CARBON INTENSITY OF BIOFUELS

As we discuss in Scully et al. 2021, the components of greenhouse gas (GHG) LCA for corn starch ethanol can be consolidated into emissions categories that include farming, fuel production, LUC, and tailpipe.[16] The carbon emissions contribution of each component is projected through the modeling of both measured and estimated data.[17] When the carbon intensity of each category is summed to reflect the total impact of corn starch ethanol, LUC emissions – in particular iLUC – can sometimes account for a large percentage of the total, or most of the total depending on the approach, especially for unrefined models.[18,19]

Policy decisions related to biofuel use are shaped by estimates for the CI value of corn ethanol. With iLUC representing a potentially large component of the CI of corn ethanol, it is important that iLUC estimates are credible and reflect the best available science. Agencies making policy decisions based on a review of multiple iLUC estimates should carefully investigate the credibility of each estimate and not apply equal consideration to estimates that fail to incorporate the best available science.

### ILUC MODEL CHARACTERISTICS AND PARAMETERS

Agroeconomic modeling is often used to estimate the GHG emissions from iLUC caused by a given scenario.[20] This practice involves a range of assumptions and uncertainty, particularly given that some empirical data does not even support the notion that biofuel production is linked

[16] Scully et al. 2021a.
[17] https://www.epa.gov/renewable-fuel-standard-program/lifecycle-analysis-greenhouse-gas-emissions-under-renewable-fuel
[18] Brandão, M., Azzi, E., Novaes, R.M., and Cowie, A., 2021. The modelling approach determines the carbon footprint of biofuels: the role of LCA in informing decision makers in government and industry. Cleaner Environmental Systems, 2, p.100027.
[19] Wicke, B., Verweij, P., Van Meijl, H., Van Vuuren, D.P., and Faaij, A.P., 2012. Indirect land use change: review of existing models and strategies for mitigation. Biofuels, 3(1), pp.87-100.
[20] Coordinating Research Council. 2012. Transportation Fuel Life Cycle Analysis: A Review of Indirect Land Use Change and Agricultural N2O Emissions. CRC Project. No. E-88-2.

with iLUC,[21] as we will discuss later in this letter. Models are presented with an assessment question: for a specified number of additional gallons of corn ethanol production (the ethanol shock) over a certain set of years (the amortization period), how much carbon is released due to indirect land conversion over the years that follow?

We understand that not all model runs address the same question, as the quantity of the ethanol shock, the time period studied, and the amortization period can change. But even when responding to the same question, models rely on different data sources and assumptions.

Answering this type of question requires the model to predict economic outcomes and their impact on land cover change, then incorporate a chosen emissions factor database which assigns carbon stock to various land. Each step requires assumptions that can impact the total output.[22]

Models capable of these simulations include computational general equilibrium (CGE) models, which include all economic markets, and partial equilibrium (PE) models, which consider the impact on only a subset of economic sectors.[23] Simulations can also be performed by integrated assessment models (IAMs) such as GCAM, though this model type is not discussed in this letter as studies we have identified that use GCAM aim to understand the causes of uncertainty instead of refining the values of CI estimates.[24,25] In addition to the scope of markets considered, models can vary by the number of regions used to divide the world map and the model's categorization of land cover type, as well as other characteristics.[26]

In the DRIA, EPA notes three primary categories that contribute to LUC: "1) acres of cropland expansion, 2) types of land displaced by cropland expansion, and 3) GHG emissions per acre of land use change."[27] Therefore, assumptions about inputs related to these elements, such as land cover data, land use data, carbon stocks, and emissions factors, can drive the outcome of models

---

[21] IEA Bioenergy. 2022. Towards an improved assessment of indirect land-use change. Task 43 – Task 38. Report, October 2022.

[22] Khanna, M. and Crago, C.L., 2012. Measuring indirect land use change with biofuels: implications for policy. Annu. Rev. Resour. Econ., 4(1), pp.161-184.

[23] Earles, J.M. and Halog, A., 2011. Consequential life cycle assessment: a review. The International Journal of Life Cycle Assessment, 16(5), pp.445-453.

[24] Plevin, R.J., Beckman, J., Golub, A.A., Witcover, J., and O'Hare, M., 2015. Carbon accounting and economic model uncertainty of emissions from biofuels-induced land use change. Environmental science & technology, 49(5), pp.2656-2664.

[25] Mignone, B.K., Huster, J.E., Torkamani, S., O'ROURKE, P.A.T.R.I.C.K. and Wise, M., 2022. Changes in Global Land Use and CO2 Emissions from US Bioethanol Production: What Drives Differences in Estimates between Corn and Cellulosic Ethanol?. Climate Change Economics, 13(04), p.2250008.

[26] Unnasch, S., T. Darlington, J. Dumortier, W. Tyner, J. Pont and A. Broch (2014) CRC Report No. E-88-3. Study of Transportation Fuel Life Cycle Analysis: Review of Economic Models Used to Assess Land Use Effects. Prepared for Coordinating Research Council Project E-88-3.

[27] EPA. 2022b. DRIA.

that answer the same question, resulting in varying iLUC estimates. Other assumptions, such as price elasticity of demand, can also influence model results.[28]

### MODEL RELIABILITY

Knowing that the selected parameters can influence the output, we next investigate the reliability of models, which here is defined as whether models reach similar results when offered the same assessment question. Most current iLUC estimates for corn starch ethanol, including models developed in the U.S. and Europe, fall within a relatively narrow range. As shown in Figure 1, these current estimates are considerably lower than findings published by EPA in 2010 and CARB in 2015/2018. The figure, which is based on updates to Figure 2 in Scully et al. 2021, 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).[29] The four commonly relied upon models shown—GTAP-BIO, FAPRI-CARD, MIRAGE, and GLOBIOM—provide estimates that are lower than older modeling results. For reference, we also include USDA, Washington State, and Oregon State studies, which are based on review of primary LUC analyses. Results for GCAM are not included in Figure 1 because in Plevin et al. 2015, the prominent application of this model for corn starch ethanol iLUC, the authors report ranges of iLUC values and later explain that the ranges are not predictions but instead were generated to understand model sensitivity to selected parameters.[30] In that paper, the uncertainty analysis aims to determine the relative influence of individual parameter uncertainty on overall uncertainty, not reduce uncertainty.

[28] California Air Resources Board (CARB). 2015 Appendix I: detailed analysis for indirect land use change
[29] Scully et al. 2021a.
[30] Plevin et al. 2015.

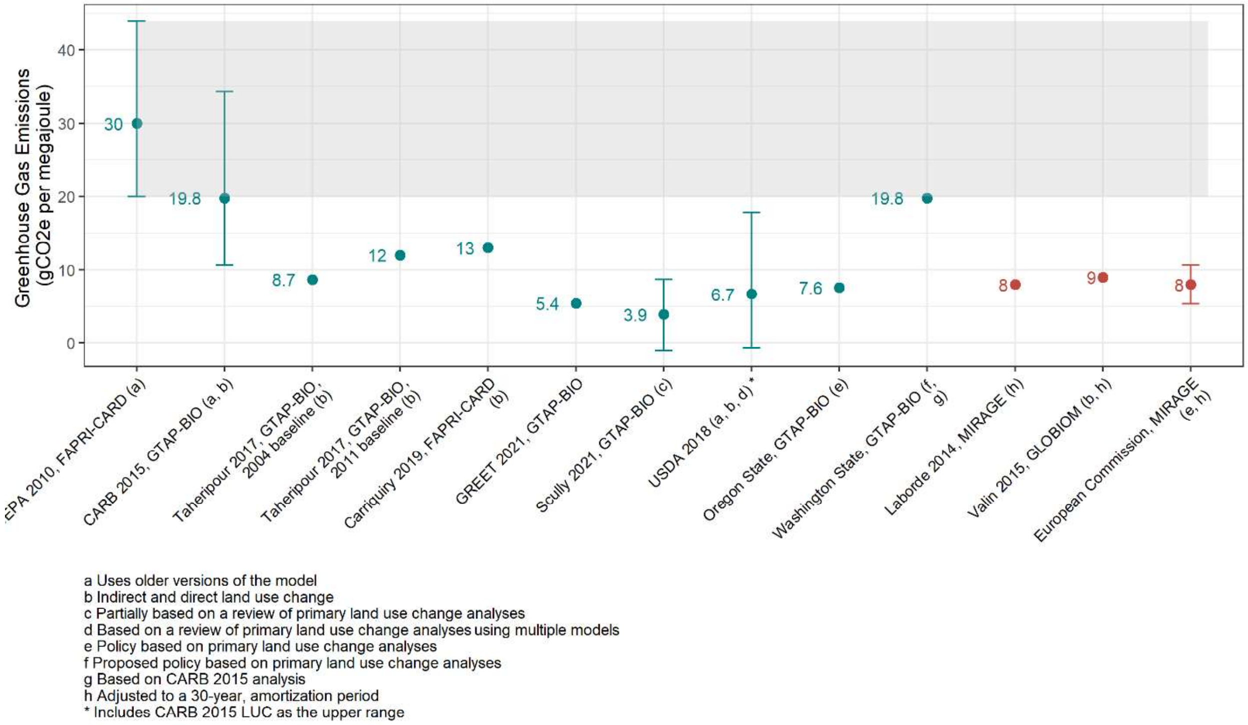



**Figure 1** Comparison of EPA's iLUC estimates with relevant most recent studies from the U.S. (teal) and Europe (red)

Several publications also recognize this downward trend in iLUC estimates for corn starch ethanol over the last decade.[31,32,33,34] As we explore in the next section, this agreement can be attributed to model adjustments and data improvements, even when different models and different adjustments are studied.

## MODEL AGREEMENT THROUGH MODEL ADJUSTMENTS AND DATA IMPROVEMENTS

Over time, models and their input data are updated to reflect the best available science, more granular regionalization, or a better understanding of economic relationships. Adjustments to

[31] 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.

[32] 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.

[33] Taheripour F, Mueller S and Kwon H. 2021a. 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.

[34] Carriquiry M, Elobeid A, Dumortier J and Goodrich R. 2019. Incorporating sub-national Brazilian agricultural production and land-use into U.S. biofuel policy evaluation. Applied Economic Perspectives and Policy, 42, pp.497-523.

models or their inputs impact iLUC estimates, and as discussed, current iLUC estimates are converging downward.

To show the effects of these improvements, we examine five studies where authors update their previous modeling of iLUC estimates for corn starch ethanol. For each scenario, we highlight the changes made and use a subsection to describe the reasoning for each adjustment. We then look at the result of the improvement to gauge how sensitive models are to various changes.

### Example 1: EPA 2009/2010 (FAPRI and FAPRI-CARD)

Our first example considers updates EPA made to their modeling during the rulemaking process for the 2010 Renewable Fuel Standard (RFS2). EPA initially developed iLUC estimates for corn starch ethanol in the proposed RFS2 rule published in 2009. After review of public comments on the initial proposed rule, EPA updated its iLUC estimates for corn ethanol in the 2010 RFS2 final rule.[35] These changes were made possible by the availability of updated studies, including numerous improvements to the Food and Agricultural Policy Research Institute-Center for Agricultural and Rural Development (FAPRI-CARD) model that are detailed in the 2010 RFS2 final rule.[36]

#### *Price-induced Crop Yields, Animal Feed Replacements, and Improved Land Use Data*

Multiple updates were applied at once for the corn starch ethanol iLUC estimate EPA developed for their final RFS2 rule. These include, but are not limited to, the addition of price-induced crop yields, refined animal feed replacement ratios, and improved satellite data.

EPA first modeled with an early FAPRI edition, then used FAPRI-CARD when it became available in early 2010. The FAPRI-CARD model introduces yield price elasticity (YDEL) factors that allow crop yields to respond to changes in price, reflecting studies of this relationship.[37,38] These price-induced crop yield elasticities were not incorporated into the early FAPRI version.[39]

---

[35] EPA. 2010. RFS2 RIA.

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

[37] Miao, R., Khanna, M. and Huang, H., 2016. Responsiveness of crop yield and acreage to prices and climate. American Journal of Agricultural Economics, 98(1), pp.191-211.

[38] Taheripour, F., Zhao, X. and Tyner, W.E., 2017a. 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.

[39] EPA. 2009. RFS2 DRIA.

The updated modeling also integrates research by Argonne National Laboratory which found that a pound of distillers grains with solubles (DGS) can replace 1.196 pounds of corn and soybean meal used for beef cattle and dairy cows, as DGS is more nutritious for these animals.[40] The new EPA analysis gradually increases the replacement rate for these specific animal feeds to reflect the improved understanding.

Additionally, multiple improvements were made to the land use data for EPA's 2010 analysis.[41] The updated EPA model relies on a newer version of the MODIS database containing more recent satellite data. Along with expanding the dataset from just 2001-2004 to now 2001-2007, the quality of the data improved from 1-kilometer resolution to 500-meter resolution. The FASOM model EPA used to determine domestic iLUC updated its list of land type categories to match the land types defined in the USDA National Agriculture Statistics Service (NASS) database, providing a more specific classification of land. Finally, FAPRI-CARD incorporated a module that divides Brazil into six regions to allow for more granular detail on the agricultural practices of each region, a feature not included in the old FAPRI model.

Table 1 shows that applying these changes reduced the iLUC estimate for corn ethanol by 50%, a difference of 30.24 $gCO_2e/MJ$. This comparison involves several adjustments at once, so individual components cannot be isolated to gauge their influence on the model. However, in general, refining the model to incorporate better data and better economic understanding significantly reduced the iLUC estimate.

[40] Arora, S., Wu, M. and Wang, M., 2011. Update of distillers grains displacement ratios for corn ethanol life-cycle analysis (No. ANL/ESD/11-1). Argonne National Lab.(ANL), Argonne, IL (United States).

[41] EPA. 2010. RFS2 RIA.

| **Table 1** | EPA'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 $CO_2$e per MJ)** |
| EPA | 2009 (original RFS2 analysis) | FAPRI | NA | 60.37[a] |
| | 2010 (revised RFS2 analysis) | Updated FAPRI-CARD, including Brazil module[c] | • Price-induced crop yields<br>• Animal feed replacements<br>• Improved land use data | 30.13[b] |

EPA 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 U.S. Environmental Protection Agency (EPA). Lifecycle Greenhouse Gas (GHG) Emissions Results Spreadsheets (30 October 2008). Docket: EPA-HQ-OAR-2005-0161.
b EPA 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 U.S. Environmental Protection Agency).
c Per RFS2 RIA (February 2010), Section 5.1.2.6.

### Example 2: Carriquiry et al. 2019 (FAPRI-CARD)

Carriquiry et al.[42] present another example using FAPRI. 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 in data made between the 2008 GHG Model and the 2016 GHG Model used to determine emissions factors include enhanced quality of spatial data and a refined relationship between crop yield.

#### *Emissions Factors and Regionalization for Brazil*

Carriquiry et al. present multiple iterations of model runs to allow for a helpful comparison. The authors start with a 2016 version of FAPRI-CARD that relies on a 2008 GHG model to determine emissions factors. Another model run is then completed with a 2016 GHG model instead of the 2008 GHG model; the updated model considers more crops and soil data with

[42] Carriquiry et al. 2019.

greater spatial resolution.[43] In an additional iteration, the 2018 GHG model is used in conjunction with the Brazil module, mentioned during the discussion of EPA's model improvements, to present more granular information for six regions of the country.

As shown in Table 2, updating only the emissions factor data yielded a 22% decrease in an iLUC estimate, a difference of 5 $gCO_2e/MJ$. Combining the enhanced emissions factor data and additional detail for Brazil doubled this impact: the estimate reduced by 44%, or 10 gCO2e/MJ.

**Table 2** 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., 2019. Incorporating sub-national Brazilian agricultural production and land-use into U.S. biofuel policy evaluation. *Applied Economic Perspectives and Policy*, 42(3), pp.497-523.

### Example 3: Taheripour & Tyner 2016 and Taheripour et al. 2017 (GTAP-BIO)

Taheripour et al.[44] describe updates to the land use module of GTAP-BIO and compare the results of multiple model runs by Taheripour and Tyner.[45] The various scenarios studied set two different years as the baseline year (2004 or 2011) and assigned two different volumes of ethanol shock. For a baseline year of 2004, the model reflects the introduction of 11.59 billion gallons (BG) of ethanol, starting with 3.41 BG and growing to 15 BG. The 2011 baseline scenario is assigned a 1.07 BG ethanol shock, growing from 13.93 BG to 15 BG. These two situations, therefore, ask different questions of the model. Below, we review how model adjustments impact the results for each of these two scenarios.

---

[43] Dumortier, J., Hayes, D.J., Carriquiry, M., Dong, F., Du, X., Elobeid, A., Fabiosa, J.F. and Tokgoz, S., 2011. Sensitivity of carbon emission estimates from indirect land-use change. Applied Economic Perspectives and Policy, 33(3), pp.428-448.

[44] Taheripour et al. 2017.

[45] 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).

*Regional Land Transformation Elasticities and Regional Land Intensification*

Before model refinement, the 2004 and 2011 scenarios estimated iLUC due to corn ethanol at 13.4 gCO2e/MJ and 23.3 gCO2e/MJ, respectively.[46] Updates to the model included regional assignments of YDEL, which range from 0.175 to 0.325, instead of the 0.25 previously used by GTAP for all regions. This change was made to support regional observations in Food and Agriculture Organization (FAO) data from the United Nations. Data from FAO also revealed that land intensification allows for more efficient use of cropland; updates to the model are tuned to better consider land intensification. As displayed in Table 3, after incorporating the adjustments, the result for the 2004 scenario reduced by nearly half (a reduction of 48%), dropping by 11.3 gCO2e/MJ to 12 gCO2e/MJ. The 2011 scenario reduced by 35%, brought down by 4.7 gCO2e/MJ to 8.7 gCO2e/MJ.

**Table 3 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) |
|---|---|---|---|
| Untuned land use module | Version 7 (2004) | 11.59 BG (3.41 to 15 BG) | 13.4 |
| Updated land use module | | | 8.7 |
| Untuned land use module | Version 9 (2011) | 1.07 BG (13.93 to 15 BG) | 23.3 |
| Updated land use module | | | 12.0 |

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, 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.

## Example 4: Laborde 2011 and Laborde 2014 (MIRAGE)

We next turn to an example from a European model, MIRAGE, which is studied by Laborde et al.[47] in a 2014 report for the European Commission (EC). The authors start with a model

[46] Taheripour et al. 2017.
[47] Laborde, D., Padella, M., Edwards, R. and Marelli, L., 2014. Progress in Estimates of ILUC with MIRAGE Model. Publications Office of the European Union.

previously run by Laborde[48] for the International Food Policy Institute (IFPRI) in 2011, which estimates 10 gCO2e/MJ from iLUC associated with corn ethanol. Laborde et al. then incorporate various updates to the modeling via a piecemeal approach that allows us to review the relative impact of each adjustment.

### *Wheat Yield Adjustments*

One change made between the models was to adjust wheat yield data to better align with projections generated by a collaboration between the Organization for Economic Co-operation and Development (OECD) and the FAO.[49] This modification resulted in no change to the iLUC estimate for corn ethanol.

### *Certain Crop Replacements Unavailable*

Laborde et al. also considered an adjustment to crop displacement. The authors noticed that the 2011 study included significant expansion into land previously used for "other oilseeds." Laborde et al.[50] questioned how realistic it would be for cereal grains to replace "other oilseeds" such as olives. When preventing the model from displacing "other oilseeds," the corn ethanol iLUC estimate increased by only 1 gCO2e/MJ.

### *Food Production is Constant*

Finally, Laborde et al. analyze the relationship between biofuel production and food consumption.[51] The authors note that agroeconomic models assume that additional biofuel demand simultaneously raises corn prices, increases the supply of corn, and lowers the demand of corn for other purposes, including food for humans and animals. With lower consumption of corn as food, the iLUC impacts of corn are reduced.

Laborde et al. were encouraged by the EC to add in an assumption that there is no reduction in food consumption due to crop price increase. When holding food consumption constant, the iLUC estimate for corn increased by 2 gCO2e/MJ to 12 gCO2e/MJ.

---

[48] Laborde, D., 2011. Assessing the land use change consequences of European biofuel policies (pp. 1-111). ATLASS Consortium.
[49] Laborde et al. 2014 and Laborde 2011.
[50] Laborde et al. 2014 and Laborde 2011.
[51] Laborde et al. 2014 and Laborde 2011.

*Combined Updates*

Combining all three potential updates, the total corn ethanol iLUC impact is 13 gCO2e/MJ.[52] When the total is amortized to 30 years instead of 20 years, the estimated iLUC of 8 gCO2e/MJ fits well with the range of improved estimates shown in Figure 1.

**Table 4** MIRAGE Central Estimates of Total Land Use Change Associated with Corn Ethanol for Biofuel Over 20 Years, ending in 2020[a,b]

| Land Use Change Model | Author | Study Year | Data and Model Adjustments | Central Estimate of LUC Emissions (g $CO_2e$ per MJ) |
|---|---|---|---|---|
| MIRAGE | Laborde | 2011 | No model/data adjustments | 10 |
| | Laborde et al. | 2014 | EU2020 wheat yields adjusted to OEC-FAO projections | 10 |
| | | | “Other oilseeds” no longer available as a crop replacement | 11 |
| | | | Food production is constant | 12 |
| | | | All adjustments combined | 13 |

MIRAGE Modeling International Relationships in Applied General Equilibrium
LUC land use change
g CO2e per MJ gram carbon dioxide equivalent emissions per megajoule

a Laborde, D., 2011. Assessing the land use change consequences of European biofuel policies. ATLASS Consortium. pp.1-111.

b Laborde, D., Padella, M., Edwards, R. and Marelli, L., 2014. Progress in Estimates of ILUC with MIRAGE Model. Publications Office of the European Union.

### Example 5: Taheripour et al. 2022 (GTAP-BIO for ETJ SAF)

Our final example focuses on sustainable aviation fuel (SAF), which is an emerging opportunity for corn ethanol. Ethanol-to-jet (ETJ) fuel is an important area of study because of limits to using battery-electric or hydrogen solutions in aircraft.[53] The value of iLUC associated with SAF differs from ethanol used in road-based vehicles as the SAF value includes production-specific technology and variations in co-production options.[54]

In a 2022 presentation at the GTAP 25th Annual Conference on Global Economic Analysis, Taheripour et al. compiled iLUC values for multiple SAF pathways.[55] Slides from the presentation show results using two different emissions factors: AEZ-F and CCLUB. Within the

[52] Laborde et al. 2014 and Laborde 2011.
[53] Zhao, X., Taheripour, F., Malina, R., Staples, M.D. and Tyner, W.E., 2021. Estimating induced land use change emissions for sustainable aviation biofuel pathways. Science of the Total Environment, 779, p.146238.
[54] Zhao et al. 2021.
[55] Taheripour, F., Steffen, M., Karami, O., Sajedinia, E., Emery, I. and Kwon, H., 2022a. Biofuels induced land use change emissions: The role of implemented emissions factors in assessing terrestrial carbon fluxes. 25th Annual Conference on Global Economic Analysis: Accelerating Economic Transformation, Diversification and Job Creation. June 8-10, 2022: Virtual.

emissions factors options, the presenters also compared results based on amortization period. This example further shows how model and data refinements can produce lower iLUC estimates, even for ETJ fuel.

### *Emissions Factors*

In a reply to comments on our Scully et al. 2021 paper, we describe the reasons for utilizing emissions factors from CCLUB over AEZ-EF.[56] This includes that the CENTURY emissions factors informing the CCLUB model use USDA data to estimate the emissions factors for cropland pasture converted to cropland. In comparison, the AEZ-EF emissions factors make a simple, blanket assumption to set cropland-pasture-to-cropland emissions factors to one half the value of emissions factors for pasture-to-cropland.[57]

When looking at a 25-year amortization period for grain-based ETJ fuel, Taheripour et al. report iLUC of 24.9 gCO2e/MJ when using AEZ-EF emissions factors and 15.6 gCO2e/MJ when using CCLUB emissions factors.[58] This a reduction of 37%, or 9.3 gCO2e/MJ, from choosing the scientifically defensible emissions factors. Results are similar when reviewing the outcomes for the 30-year amortization period. The ETJ fuel iLUC estimate using AEZ-EF yields 20.8 $gCO_2e$/MJ, while the estimate relying on CCLUB is 38% lower (7.8 $gCO_2e$/MJ lower) at 13 $gCO_2e$/MJ.

[56] Scully et al. 2021b.

[57] Taheripour, F., Mueller, S. and Kwon, H., 2021b. 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, p.127431.

[58] Taheripour et al. 2022a.

**Table 5** GTAP-BIO Central Estimates of Total Land Use Change Associated with Corn Ethanol for Jet Fuel Over 25 or 30 Years, ending in 2020[a]

| Author | Land Use Change Model | Emissions Factors and Amortization Period | Central Estimate of LUC Emissions (g $CO_2e$ per MJ)[b] |
|---|---|---|---|
| Taheripour et al. | GTAP-BIO | AEZ-EF with 25-year amortization period | 24.9 |
| | | CCLUB with 25-year amortization period | 15.6 |
| | | AEZ-EF with 30-year amortization period | 20.8 |
| | | CCLUB with 30-year amortization period | 13 |

GTAP-BIO Global Trade Analysis Project Biofuels Model
LUC land use change
g CO2e per MJ gram carbon dioxide equivalent emissions per megajoule

a Taheripour, F., Steffen, M., Karami, O., Sajedinia, E., Emery, I. and Kwon, H., 2022. Biofuels induced land use change emissions: The role of implemented emissions factors in assessing terrestrial carbon fluxes. 25th Annual Conference on Global Economic Analysis: Accelerating Economic Transformation, Diversification and Job Creation. June 8-10, 2022: Virtual.
B Grain ETJ SAF iLUC values

## CONSIDERATIONS FOR ILUC MODELING

Though iLUC represents a significant component of many estimates for the carbon intensity of corn ethanol, this contribution is difficult to estimate and verify. Uncertainty surrounds the assumptions used in iLUC modeling, though empirical observations can be used to assess how well components of iLUC modeling results reflect reality. The two subsections that follow give recommendations for dealing with uncertainty and considering empirical observations.

### Uncertainty

iLUC is particularly challenging to model because it is not possible to directly measure indirect land use change.[59] In addition, the models assume direct relationships exist between iLUC, economics, and human behavior, when in fact, national and international policy, immigration and emigration, prices of influential commodities such as oil and natural gas, severe weather events,

[59] Woltjer, G., Daioglou, V., Elbersen, B., Ibañez, G.B., Smeets, E.M.W., González, D.S. and Barnó, J.G., 2017. Study report on reporting requirements on biofuels and bioliquids stemming from the directive (EU) 2015/1513.

climate change, and other factors have large influences on the value and use of land.[60,61,62,63,64] Within the domain of the iLUC models alone, researchers hold conflicting opinions on which factors are the most influential,[65,66,67,68,69] though these variable assumptions include yield responsiveness, ease of land conversion, crop substitution, and consumption elasticity.[70,71]

Given the unknown value of iLUC caused by corn ethanol, it is best practice to try to control this uncertainty by using estimates based on recent, updated models that rely on recent, adjusted inputs. Our April 2022 "Comments on the 2022 Workshop on Biofuel Greenhouse Gas Modeling," which were delivered to EPA, detail a strategy for moving forward with policy decisions despite uncertainty in iLUC estimates. We recommend following the example employed by existing literature reviews[72,73] to conduct a systematic review of existing estimates that carefully filters for credible results. This can be in concert with efforts to further refine iLUC model parameters. Our proposed approach for a literature review does differ from EPA's literature review in a critical way: we encourage the use of a filter or weighting scheme to prioritize the most reliable results, while EPA's range in DRIA Table 4.2.3.13-1 currently presents all well-to-wheel CI results without removing or downweighing inferior studies. The text of the DRIA does, however, address the variation in study quality by noting on page 145 that "We sometimes bring other models and empirical studies into the discussion as comparison points, but we otherwise set them aside to focus on models that are designed to evaluate

---

[60] Shams Esfandabadi, Z., Ranjbari, M. and Scagnelli, S.D., 2022. The imbalance of food and biofuel markets amid Ukraine-Russia crisis: A systems thinking perspective. Biofuel Research Journal, 9(2), pp.1640-1647.

[61] Olesen, J.E. and Bindi, M., 2002. Consequences of climate change for European agricultural productivity, land use and policy. European journal of agronomy, 16(4), pp.239-262.

[62] Shrestha, D.S., Staab, B.D. and Duffield, J.A., 2019. Biofuel impact on food prices index and land use change. Biomass and Bioenergy, 124, pp.43-53.

[63] Park, S., Chapman, R. and Munroe, D.K., 2022. Examining the relationship between migration and land cover change in rural US: evidence from Ohio, United States, between 2008 and 2016. Journal of Land Use Science, 17(1), pp.60-78.

[64] McKay, D., 2003. Cultivating new local futures: Remittance economies and land-use patterns in Ifugao, Philippines. Journal of Southeast Asian Studies, 34(2), pp.285-306.

[65] Plevin et al. 2015.

[66] Taheripour et al. 2017a.

[67] Plevin, R.J., Jones, J., Kyle, P., Levy, A.W., Shell, M.J. and Tanner, D.J., 2022. Choices in land representation materially affect modeled biofuel carbon intensity estimates. Journal of cleaner production, 349, p.131477.

[68] ICAO. 2019. CORSIA Supporting Document: CORSIA Eligible Fuels – Life Cycle Assessment Methodology. June 2019.

[69] Transport Energy Strategies. 2021. Well-to-Wheels Carbon Intensity for Ethanol Blended Fuels. Report, September 2021.

[70] Khanna et al. 2012.

[71] Woltjer et al. 2017.

[72] Scully et al. 2021a.

[73] 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.

hypothetical scenarios and project future effects."[74] This statement by EPA should be incorporated into the CI results they present.

If we apply this logic to the studies captured in Figure 1 above, we see that improved models and adjusted data work to reduce uncertainty. Even when considering different models (GTAP-BIO, FAPRI-CARD, MIRAGE, and GLOBIOM), different parameter values, and different adjustments, the results from these studies converge downward. Eight of the eleven results range from 3.9 to 9 g$CO_2$e/MJ, with two at 12 and 13 g$CO_2$e/MJ and one at the CARB 2016 value of 19.8 g$CO_2$e/MJ. This is not to say that all models and analyses should be weighted equally; in Scully et al. 2021 we conducted a more in-depth evaluation of LUC studies.[75] We considered 26 CI LUC studies (including the U.S. based analyses shown in Figure 1) published from 2008 to 2020 and filtered those studies based on a critical evaluation of the underlying agroeconomic model, economic data year, YDEL, and incorporation of land intensification. We determined a credible range for LUC of -1.0 to 8.7 gCO2e/MJ with a central best estimate of 3.9 gCO2e/MJ. European studies were outside the scope of Scully et al. 2021, but Figure 1 shows that iLUC central estimates from these studies (8 and 9 gCO2e/MJ) fall within or very close to our identified range, which we still consider credible based on best available science. In Part II, we provide an example of a process that EPA may consider to evaluate studies against a set of criteria and assign greater weight to studies that reflect the best available science.

### Empirical Observations

The case for using updated iLUC values is further supported when reviewing empirical data. An October 2022 report by the International Energy Agency Bioenergy Technology Collaboration Program (IEA Bioenergy) compares predicted trends from iLUC modeling with observed data.[76]

When looking at the empirical information in the IEA study, there is no indication of iLUC associated with biofuel demand that is suggested by the agroeconomic models. Specifically, the IEA report concludes that "Contrary to modelled relationships, statistics showed **no link** between expansion of U.S. biofuel production between 2005 and 2015 and corn production, corn export, or deforestation in Brazil."[77] These observations conflict with older, unrefined iLUC analyses that link increased biofuel demand with high iLUC estimates; the empirical data instead supports the lower iLUC results produced from updated models. Below, we highlight some of the evidence IEA finds in contradiction to the assumptions about biofuel demand.

[74] EPA. 2022b. DRIA.
[75] Scully et al. 2021.
[76] IEA Bioenergy. 2022. (emphasis added).
[77] IEA Bioenergy. 2022.

First, we look at IEA's assessment of trends in animal production. IEA dispelled predictions that the U.S. livestock sector would be harmed by the increased designation of corn for ethanol. Data from FAO actually shows that U.S. meat production increased between 2005 and 2015. Though use of corn for animal feed did decline, DGS was made more available and was used as feed instead. DGS allowed for more efficient animal production, as it contains more proteins and key nutrients.

Next, IEA doubts a relationship between ethanol and corn price, which we have also questioned in prior letters. IEA calls attention to fluctuations in the price of corn, showing that the high corn prices in 2012 were likely associated with drought and that 2017 corn prices are close to the prices from 1996. In disconnecting ethanol production and corn price, IEA also reminds readers that simultaneous observations do not indicate causality.

This comparison with statistics shows that biofuel demand and iLUC are not necessarily linked as previously indicated by early modeling. In the future, carefully-constructed empirical analyses have the potential to further support improved estimates.

## PART II: RESPONSE TO EPA'S INVITATION FOR COMMENT

On Federal Register page 80611 of the Set Proposal, EPA directly lists a handful of topics for comment. We address each in the sections that follow.

### RANGE AND APPROACH

We begin with EPA's first call for input from the Set Proposal:

> EPA: We invite comment on the range of lifecycle GHG emissions impacts of the biofuels considered as part of this proposed rulemaking, and input on the proposed approach, or other potential approaches, for conducting a model comparison exercise for the final rule.[78]

We are pleased to see EPA has taken the approach of a literature review. With the breadth of existing literature available, we have previously recommended this type of method to EPA as it provides timely information needed for policy decisions.

While we applaud EPA's efforts to further understand the models and conduct their own new analysis using combined models, for the purposes of the current rule, there is enough information in the literature as it exists to support EPA's conclusion that corn starch ethanol offers significant GHG reductions. The current rule need not be delayed by the additional time needed to complete a comprehensive new modeling exercise.

That said, we do agree this new analysis is worthwhile, particularly to refresh the values for components such as farming and co-products that have become more efficient over time.

EPA should offer for public review and comment on the iLUC and CI numbers it intends to generate from its new modeling exercise before the values are finalized. This step of allowing scientific scrutiny keeps with the processes employed for the RFS2, where comments on the draft impact analysis were reviewed to allow adjustments to the analysis before the estimates became part of the final record used to make policy decisions.

#### Well-to-Wheel Emissions

Based on our 2021 systematic review, the best available science suggests that corn starch ethanol has a CI of 51 $gCO_2e/MJ$, representing an approximately 46% reduction in GHG emissions

[78] EPA. 2022a.

relative to fossil fuels.[79] Our analysis identified a credible range for well-to-wheel emissions of 37.6 to 65.1 gCO2e/MJ. EPA's literature review, which used a broad lens to include a wider range of studies, found CI values ranging from 38 to 116 gCO2e/MJ. As we will discuss in the sections that follow, there is variation in the quality of the studies included in EPA's list we recommend EPA address this variation by assigning more weight to high-quality studies and down-weighting studies that do not meet a prescribed standard.

### Upstream Emissions

When focusing only on upstream emissions, the studies included in the DRIA report a range of 9 to 51 gCO2e/MJ. Our Scully et al. 2021 study sits at the lowest end of this range. EPA notes on page 174 of the DRIA that our estimate includes a "relatively large" co-product credit for DGS. However, our co-product credit estimates are based on analyses that follow the ISO 14044 standard for LCAs and that consider that DGS sold as animal feed can displace urea, corn, and soybean meal in different quantities depending on which type of livestock is being fed.[80,81,82,83,84,85] We considered the emission co-product credit from DGS in our analysis and generated a central estimate of -12.8 g$CO_2$e/MJ with range of -13.5 to -12.1 g$CO_2$e/MJ based on analyses from ANL, CARB, and USDA using GREET that conform with the ISO 14044 standard for addressing co-product credits in LCAs.[86,87,88,89,90,91] GREET (the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation model) is the most widely used tool and database over the prior 10 years for assessing GHG emissions from corn ethanol in the U.S.[92]

---

[79] Scully et al. 2021.

[80] ANSI. Environmental Management - Life Cycle Assessment - Requirements And Guidelines ISO 14044:2006 specifies requirements and provides guidelines for 2020 [Available from: https://webstore.ansi.org/Standards/ISO/ISO140442006?gclid=Cj0KCQjwoJX8BRCZARIsAEWBFMJ8CasSwv-htj7sk3pm674E6GMXi4-kqpIIJ4duY2kWkJ-Wx-Dz1gsaAtBJEALw_wcB

[81] CARB. CA-GREET 2.0 Model 2015 [updated May 6. Available from: https://ww2.arb.ca.gov/resources/documents/lcfs-life-cycle-analysis-models-and-documentation.

[82] CARB. CA-GREET 3.0 Model 2019 [updated January 4, 2019. Available from: https://ww2.arb.ca.gov/resources/documents/lcfs-life-cycle-analysis-models-and-documentation.

[83] Argonne National Laboratory (ANL). GREET 1 2016. GREET 1 Series (Fuel-Cycle Model): Argonne National Library; 2016.

[84] ANL. GREET 1 2019. GREET 1 Series (Fuel-Cycle Model): Argonne National Laboratory; 2019.

[85] ANL. GREET 2020. GREET 1 Series (Fuel-Cycle Model): Argonne National Laboratory; 2020.

[86] ANSI. Environmental Management - Life Cycle Assessment - Requirements And Guidelines ISO 14044:2006 specifies requirements and provides guidelines for 2020 Available from: https://webstore.ansi.org/Standards/ISO/ISO140442006?gclid=Cj0KCQjwoJX8BRCZARIsAEWBFMJ8CasSwv-htj7sk3pm674E6GMXi4-kqpIIJ4duY2kWkJ-Wx-Dz1gsaAtBJEALw_wcB

[87] CARB. CA-GREET 2.0.

[88] CARB. CA-GREET 3.0.

[89] ANL. GREET 1 2016.

[90] ANL. GREET 1 2019.

[91] ANL. GREET 2020.

[92] ANL. GREET Model Platforms. Argonne National Laboratory (ANL); 2020 October 9, 2020.

## Land Use Change

As reinforced in Scully et al. 2021 and Part I above, refined models and updated data that reflect the best available science report smaller CI contributions from LUC than the results of the initial LUC research. In Scully et al. 2021, we critically reviewed 26 LUC CI values published from 2008 to 2020 and evaluated the underlying agroeconomic model, economic data year, YDEL, and incorporation of land intensification. We also calculated an updated dLUC emission value using the 2020 ANL CCLUB model with CENTURY-based emission factors for characterizing soil organic carbon (SOC). In a reply to comments on our Scully et al. 2021 paper, we describe the reasons for utilizing emissions factors from CCLUB over AEZ-EF.[93] This includes that the CENTURY emissions factors informing the CCLUB model use detailed USDA data to estimate the emissions factors for cropland pasture converted to cropland. In comparison, the AEZ-EF emissions factors make a simple, blanket assumption that cropland-pasture-to-cropland emissions factors are one half the value of emissions factors for pasture-to-cropland.[94] Our calculations result in net sequestration of soil carbon when planting on land that is categorized as cropland pasture, a land type that is often rotated. We discuss this concept in our 2021 response to Spawn-Lee et al., and papers by Taheripour et al. and Claassen et al. further detail these observations and how models account for this sequestration.[95,96]

## EVALUATING AND WEIGHTING STUDY RESLTS

This next section reflects the intersection of two prompts from EPA:

> EPA: We invite comment on the scope of this review as well as comment on the specific studies included in the review.
>
> EPA: Given the different types of modeling frameworks currently available, we also invite comments on the appropriateness of these different approaches for conducting lifecycle GHG emissions analysis and whether model results can or should be weighted if we choose a multi-model approach to assessing GHG emissions for purposes of RFS volumes assessment.[97]

The results of EPA's literature review include twenty results from nine studies, as summarized in Table 6 below. The list contains studies relying on both established models and other approaches. Even within these approaches, there is variation in the quality of studies. We

[93] Scully et al. 2021b.
[94] Taheripour et al. 2021b.
[95] Taheripour et al. 2021b.
[96] Claassen, R., Carriazo, F., Cooper, J.C., Hellerstein, D. and Ueda, K., 2011. Grassland to cropland conversion in the Northern Plains: the role of crop insurance, commodity, and disaster programs (No. 1477-2017-4005).
[97] EPA. 2022a.

appreciate the scientific integrity of including a broad range of research, but when all studies are not of the same quality, they cannot be considered equally. For that reason, we recommend evaluating studies against a set of criteria and assigning more weight to studies that reflect the best available science. We provide a set of example criteria that EPA can consider incorporating into a study evaluation process based on the criteria discussed below. Our evaluation process outlined below is not intended to be definitive but rather provides an example EPA may consider for the construction of their own weighting system.

**Table 6** Studies Considered in the Range of Well-to-Wheel CI Results for Corn Starch Ethanol from EPA's 2022 DRIA

| Study | Agroeconomic Model | Result Considered |
|---|---|---|
| BEIOM (Avelino et al 2021) | BEIOM | BEIOM (2021)/Avg. Dry Mill |
| Brandão 2022 | None | Brandão (2022) |
| CARB 2018 | GTAP-BIO | CARB (2018)/GTAP-BIO+AEZ-EF/Dry Mill/High LUC |
| | | CARB (2018)/GTAP-BIO+AEZ-EF/Dry Mill/Mean LUC |
| | | CARB (2018)/GTAP-BIO+AEZ-EF/Dry Mill/Low LUC |
| EPA 2010 | FASOM-FAPRI | RFS2 rule (2010)/FASOM-FAPRI/NG Dry DDGS/High LUC |
| | | RFS2 rule (2010)/FASOM-FAPRI/2022 Avg NG Dry Mill/Mean LUC |
| | | RFS2 rule (2010)/FASOM-FAPRI/Adv. NG Dry Mill/Low LUC |
| GREET 2021 | GTAP-BIO | GREET (2021)/GTAP-BIO+CCLUB/NG Dry Mill DDGS |
| | | GREET (2021)/GTAP-BIO+CCLUB/Avg Plant |
| | | GREET (2021)/GTAP-BIO+CCLUB/Gen 1.5 w/ DCO |
| | | GREET (2021)/GTAP-BIO+CCLUB/NG Dry Mill WDGS |
| Lark et al 2022 | None | Lark et al. (2022)/Other/RFS2 RIA |
| | | Lark et al. (2022)/Other/CA-LCFS |
| | | Lark et al. (2022)/Other/GREET |
| Lee et al 2021 | GTAP-BIO | Lee et al. (2021)/GTAP-BIO+CCLUB/2019 |
| Lewandrowski et al 2019 | FASOM + GTAP-BIO | Lewandrowski et al. (2019)/FASOM+GTAP-BIO/2022 BAU |
| Scully et al 2021 | GTAP-BIO | Scully et al. (2021)/GTAP-BIO+CCLUB/High LUC |
| | | Scully et al. (2021)/GTAP-BIO+CCLUB/Central LUC |
| | | Scully et al. (2021)/GTAP-BIO+CCLUB/Low LUC |

Data adapted from: EPA. 2022d. Rulemaking Docket: Set Rule for the Renewable Fuel Standard Program, Supporting and Related Material. LCA Table.

## Scope

In terms of the scope of studies, we appreciate the focus on recent research published after EPA's 2010 RFS2 analysis. Later in this section, we will encourage the inclusion of additional studies published since the RFS2. As mentioned, we do support EPA's investigation of new approaches in efforts to dial in estimates, but we again caution against relying heavily on untested methods.

## Criteria for Evaluating Studies and Models

In order to include all studies without assigning equal weight to each, we recommend using criteria to evaluate the strengths and weaknesses of each study, similar to systematic reviews and meta-analyses where attributes are preidentified and works are rated by those attributes. Assessing each study against a standard will indicate which studies score higher or lower, thus providing a framework that allows the up-weighting of studies that are more reliable and/or down-weighting of studies that are less reliable.

In our April 2022 comments to EPA after the Biofuels Workshop, we defined "best available science" as research and tools that are "current, credible, transparent, complete, and capable of being reproduced." With these adjectives in mind, below we present some potential evaluation criteria for EPA's consideration. These criteria consider whether each study follows a generally **accepted approach**, utilizes **refined modeling tools**, uses **complete data**, and documents a **transparent process.** Our assessment method and the elements of our evaluation process outlined in the subsections that follow are not necessarily definitive but instead provide examples EPA may consider for the construction of their own weighting system.

Note that the assessment that follows is for example purposes only. The ratings shown are not necessarily a definitive indicator of quality or reliability but serve to highlight strengths and weaknesses of the studies presented. For simplicity, we assign a binary Yes/No in our evaluation. The allocation of a "No" does not indicate an absolute nonexistence of a trait but instead grades the study relative to the full set of studies under consideration. Likewise, a "Yes" does not indicate absolute existence of a trait and, again, reflects the study relative to the full set of studies considered. There are multiple potential approaches one could take to expand on this concept. For example, one could weight criteria differentially rather than equally as we have done. For instance, the refined modeling tools criterion could be given a relatively large weight to ensure prioritization of results from studies based upon the best available science.

### *Accepted Approach*

Our first criterion considers whether the study uses a generally accepted approach. We start sorting studies using a line drawn by EPA in the current DRIA, which sets five models (GREET, GLOBIOM, GTAP-BIO, ADAGE, GCAM) apart from other modeling approaches. On page 119 of the DRIA, in Section 4.2.2, EPA explains that the five listed models, which were discussed at last year's Biofuels Workshop, can be relied on to "evaluate significant indirect emissions, including indirect land use change emissions."[98] Accepted models have been subject to replication and scrutiny that bolster their reliability. Other models and approaches, however, are mentioned in the DRIA "for informational purposes, but we do not think they meet our statutory requirements under the CAA to evaluate all significant direct and indirect emissions," as EPA notes on page 145.[99]

Studies relying on the models listed by EPA meet the criteria. Studies using FASOM/FAPRI or MIRAGE also meet the criteria, given that EPA and the European Commission have relied on results from these models to inform energy policy. Models using other approaches will currently not meet the criteria. While the models introduced above are those that are generally accepted today, other models may receive enough replication and scrutiny in the future to later enter this "accepted" category. Inversely, models which fall out of usage in the scientific literature may eventually be removed from this "accepted" category.

### *Refined Modeling Tools*

A reliable agroeconomic model is necessary to incorporate market responses to changes in demand. The recent *Current Methods for Life Cycle Analyses of Low-Carbon Transportation Fuels in the United States* report by the National Academies of Science (NAS) explains that "As models used to assess induced LUC have been updated over the last decade, they have incorporated new elements to reflect agricultural practices in finer detail, including multi-cropping, new land categories such as idled or marginal cropland, and new forms of market mediated responses to biofuel demand."[100] As discussed in Part I, well-developed agroeconomic models will have been tested and refined to improve the accuracy of results and, thus, meet our evaluation criteria. Studies that use versions of models that have been superseded by more complete, better tuned models are no longer reflective of the best available science and do not meet our assessment criteria. In an effort to better evaluate newer models/approaches that have not had time to evolve, in this category we may also consider whether the study produces results that align with empirical data, as a rough strategy to assess tool performance.

---

98 EPA. 2022b. DRIA.

99 EPA. 2022b. DRIA. Page 143

100 National Academies of Sciences, Engineering, and Medicine, 2022. Current Methods for Life Cycle Analyses of Low-Carbon Transportation Fuels in the United States.

To highlight the utility of calibrating model results to real-world observations and data, we turn to other areas of research where this practice is employed. Keeping a focus on EPA, we will look at an air quality modeling tool the Agency developed called The Community Multiscale Air Quality Modeling System (CMAQ). Ren et al. 2022 describe how estimates for ozone concentrations modeled by CMAQ often differ from observed concentrations.[101] The authors, which include an EPA scientist, explain that "data fusion" can be used to improve model results by making adjustments based on observed data. This process is employed in von Stackelberg et al. 2013, where model outputs are scaled based on measured data; the team includes a researcher from EPA's National Exposure Research Laboratory (NREL).[102] EPA also used this process in the May 2020 Anti-backsliding Study to create "fused fields" for ozone and $PM_{2.5}$ CMAQ estimates "where the model output has been adjusted using monitored data."[103] The application of this process by EPA itself reinforces the merit of tuning models to empirical data.

### *Complete Data*

The next criterion considers whether the study is missing the consideration of key data or if the research is otherwise incomplete. Studies with significant gaps in economic or geographic scope will not meet the criteria.

### *Transparent Process*

Our final test asks if the study employs a transparent process. This criterion accounts for whether information needed to understand the methodology and reproduce the study is available. As noted in recommendations by NAS, "reporting one's data sources transparently can increase confidence in LCA results and enable reproducibility."[104] Not meeting the transparency criterion means that a paper has less publicly available backup information relative to the other studies in the set and likely cannot be reproduced from the information available to the public.

## Assessing Included Studies

Below, we assess each study used in Figure 4.2.3.3-1 of EPA's DRIA using the four criteria. We first provide a chart summarizing whether studies meet each condition by indicating "Yes" or

[101] Ren, X., Mi, Z., Cai, T., Nolte, C.G. and Georgopoulos, P.G., 2022. Flexible Bayesian ensemble machine learning framework for predicting local ozone concentrations. Environmental Science & Technology, 56(7), pp.3871-3883.

[102] von Stackelberg, K., Buonocore, J., Bhave, P.V. and Schwartz, J.A., 2013. Public health impacts of secondary particulate formation from aromatic hydrocarbons in gasoline. Environmental Health, 12(1), pp.1-13.

[103] EPA. 2020. Clean Air Action 211(v)(1) Anti-backsliding Study. EPA-420-R-20-008.

[104] NAS. 2022.

"No." The number of "Yes" responses are tallied to assign a score to each study, where a study receiving a higher score meets more criteria. We then provide additional explanation for each score, along with further commentary on the studies. Studies are introduced in alphabetical order.

### *BEIOM (Avelino et al. 2021)*

| Criteria | Criteria Met | Evaluation |
|---|---|---|
| Accepted Approach | No | Other approach |
| Refined Modeling Tools | No | Refinements are needed and authors note inconsistencies with observed data |
| Complete Data | No | Only considers the U.S. and does not include LUC |
| Transparent Process | Yes | Model is well documented and available for public use |
| Score: | 1/4 | |

EPA includes results from the Bio-based circular carbon economy Environmentally extended Input−Output Model (BEIOM) reported by Avelino et al. 2021.[105] The BEIOM is based on an Environmentally-Extended Input-Output (EEIO) model called USEEIO, originally developed by EPA's NREL.[106] Substantial documentation and modeling files for the base USEEIO are available for public review and trial.[107] Avelino et al. complement this with extensive documentation detailing their process and the steps used to adapt the USEEIO model.

The BEIOM model is described in Lamers et al. 2021, to which all authors from Avelino et al. 2021 contribute, where it is noted that the BEIOM model only studies the economy and emissions of the U.S. and does not capture international interactions, rendering the data incomplete.[108] In closing their paper, Avelino et al. note refinements that are still needed, such as breaking down the U.S. into regions and addressing the conflicting environmental and economic assignment of impacts by international companies operating in the U.S., an issue intrinsic to EEIO databases.[109] Additionally, Lamers et al. 2021 note that the constant crop prices assigned by the BEIOM model do not match the elastic crop prices observed in the real world.[110] While

[105] Avelino, A.F., Lamers, P., Zhang, Y. and Chum, H., 2021. Creating a harmonized time series of environmentally-extended input-output tables to assess the evolution of the US bioeconomy-A retrospective analysis of corn ethanol and soybean biodiesel. Journal of Cleaner Production, 321, p.128890.
[106] NERL. Bioenergy Models. BEIOM. https://bioenergymodels.nrel.gov/models/42/
[107] EPA. US Environmentally-Extended Input-Output (USEEIO) Technical Content. https://www.epa.gov/land-research/us-environmentally-extended-input-output-useeio-technical-content [Accessed 3 Feb 2023]
[108] Lamers, P., T. Avelino, A.F., Zhang, Y., D. Tan, E.C., Young, B., Vendries, J. and Chum, H., 2021. Potential socioeconomic and environmental effects of an expanding US bioeconomy: an assessment of near-commercial cellulosic biofuel pathways. Environmental Science & Technology, 55(8), pp.5496-5505.
[109] Avelino et al. 2021
[110] Lamers et al. 2021

the BEIOM model does build on the existing work of the USEEIO, further refinements are needed to improve this tool.

### *Brandão 2022*

| Criteria | Criteria Met | Evaluation |
|---|---|---|
| Accepted Approach | No | Other approach |
| Refined Modeling Tools | No | Inconsistencies with empirical data noted by IEA; no agroeconomic model; iLUC model still needs improvements |
| Complete Data | No | No economic model; key parameters not captured |
| Transparent Process | No | Model documentation is behind a paywall |
| Score: | 0/4 | |

As described in EPA's DRIA, Brandão 2022 does not utilize an economic model.[111] This prevents the study from incorporating market effects and efficiencies stemming from demand-induced intensification. Instead, the researcher uses an alternate approach of making estimates based on differences in corn production for ethanol over production from 1999 to 2018.[112] This framework essentially ignores the intricacies and relationships of the demand for products and models only the estimated demand for land.[113]

To estimate iLUC, Brandão utilizes a modified version of the iLUC Club 2.-0 model developed by Schmidt et al. 2015.[114,115] Access to the model and its documentation lie behind a membership paywall of 3,500 EUR (approximately $3,756 USD),[116] hindering transparency and review by others. While we recognize that scientific papers often do require purchase to review, extensive documentation for the other models considered by EPA is available to the public at no charge. Di Lucia et al. 2019 provide a review of the iLUC Club model, in which the authors comment that while this model does incorporate increased yields, the intensification is "based on global past trends even though global past trends might not be fully representative of the specific conditions in the case study area."[117] This can be contrasted with updates to FAPRI/FASOM and GTAP-BIO that assign regional intensification factors to Brazil. Further, Schmidt et al. note in their

---

[111] DRIA 2022

[112] Brandão, M., 2022. Indirect Effects Negate Global Climate Change Mitigation Potential of Substituting Gasoline With Corn Ethanol as a Transportation Fuel in the USA. Frontiers in Climate, 4, p.33.

[113] Brandão, M., 2022.

[114] Brandão, M., 2022.

[115] Schmidt, J.H., Weidema, B.P. and Brandão, M., 2015. A framework for modelling indirect land use changes in life cycle assessment. Journal of Cleaner Production, 99, pp.230-238.

[116] https://lca-net.com/clubs/iluc/

[117] Di Lucia, L., Sevigné-Itoiz, E., Peterson, S., Bauen, A. and Slade, R., 2019. Project level assessment of indirect land use changes arising from biofuel production. GCB Bioenergy, 11(11), pp.1361-1375.

paper introducing the model that "price-elasticity effects are not included."[118] As such, we consider the data incomplete.

Brandão describes that "The iLUC component of the model is based on Schmidt et al. (2015)"[119] but does not clarify modifications made to the model nor which version served as the starting point. Early updates to the model, which was first released in 2011, served to improve functionality and make corrections.[120,121] Later updates were made to incorporate additional data,[122] such as accounting for all crops,[123] but Schmidt and DeRose note that there is still "potential for improving the regionalization of the market for land in order to improve the identification of final land use impacts."[124] Further need for refinement is signaled by conflicts with empirical data identified in the 2022 IEA report we introduced in Part I of our letter.[125] For example, page 36 of the IEA report explains that 'Projected changes in U.S. corn area were overstated in Brandão (2022). While corn harvested area increased by 2.2 million ha, U.S. crop area did not increase. It declined by nearly 6 million ha." Given the improvements needed to regionalize the model and the inconsistencies with empirical data, this study does not meet our criteria for utilizing refined modeling tools.

### *CARB 2018*

| Criteria | Criteria Met | Evaluation |
|---|---|---|
| Accepted Approach | Yes | GTAP-BIO is a generally accepted model |
| Refined Modeling Tools | No | Updated GTAP-BIO model available |
| Complete Data | Yes | Comprehensive geographic and economic scope |
| Transparent Process | Yes | Model runs are downloadable and well documented |
| Score: | 3/4 | |

EPA uses the three results from the CARB 2018 CA-GREET 3.0 study, which relies on the widely accepted GTAP-BIO model to estimate economy-wide impacts domestically and internationally. However, per Table 38 of its supplemental documentation, CARB's 2018 analysis copies the same LUC value determined from their 2015 CA-GREET 2.0 assessment

---

118 Schmidt et al. 2015.
119 Brandão, M., 2022.
120 https://lca-net.com/projects/show/indirect-land-use-change-model-iluc/
121 https://lca-net.com/clubs/iluc/
122 Schmidt, J. and De Rosa, M., 2018a. Enhancing Land Use Change modelling with IO data. Slides from presentation at the SETAC Europe 28th Annual Meeting, Rome 13-17 May 2018.
123 Schmidt, J. and De Rosa, M., 2018b. Enhancing Land Use Change modelling with IO data. Abstract of presentation at the SETAC Europe 28th Annual Meeting, Rome 13-17 May 2018.
124 Schmidt and De Rosa. 2018b.
125 IEA Bioenergy. 2022.

without recalculating the results.[126] That LUC value was determined with an older version of GTAP-BIO that does not incorporate updates and adjustments researchers later made to the model.[127] While GTAP-BIO itself has undergone refinements, this old iteration of the model is outdated and does not meet the criteria for a refined tool. CARB's analysis is well documented, [128] and the customized GTAP-BIO model is available for download and replication after registering for a free account.[129,]

### *EPA 2010*

| Criteria | Criteria Met | Evaluation |
|---|---|---|
| Accepted Approach | Yes | FASOM/FAPRI is a generally accepted model |
| Refined Modeling Tools | No | Updated FAPRI model available |
| Complete Data | Yes | Comprehensive geographic and economic scope |
| Transparent Process | Yes | Model documentation is available and analysis is well documented |
| Score: | 3/4 | |

EPA's range of studies includes three results from EPA's 2010 analysis for the RFS2. The analysis uses FASOM to estimate domestic LUC and FAPRI to estimate international LUC by modeling across food and agricultural sectors. Though all resources are not compiled in one location due to the model changing home universities, the FAPRI model used for international LUC has solid, publicly available historical documentation, mostly recorded in a repository managed by the University of Missouri.[130,131,132] researchers at Iowa State's Center for Agricultural and Rural Development (CARD) provided detailed documentation specific to EPA's analysis[133] The regulatory impact analysis for EPA's 2010 RS2 also provided ample description of the modeling completed using FASOM and FAPRI.[134]

---

[126] CARB. 2018. CA-GREET3.0 Supplemental Document and Tables of Changes. Available from: https://ww2.arb.ca.gov/resources/documents/lcfs-life-cycle-analysis-models-and-documentation

[127] CARB. 2015. Staff report: calculating carbon intensity values from indirect land use change of crop-based biofuels. Available from: https://ww2.arb.ca.gov/resources/documents/lcfs-life-cycle-analysis-models-and-documentation

[128] CARB. 2015. Detailed Analysis for Indirect Land Use Change. Available from: https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/iluc_assessment/iluc_analysis.pdf

[129] GTAP. 2014. GTAP Resources: CARB 2016 September Model. https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=4577

[130] University of Missouri. FAPRI-MU Reports. https://www.fapri.missouri.edu/publications/reports/

[131] Meyers, W.H., Westhoff, P., Fabiosa, J.F. and DJ, H., 2010. The FAPRI global modelling system and outlook process. Journal of international agricultural trade and development, 6(1), pp.1-19.

[132] FAPRI. 2004. Documentation of the FAPRI Modeling System. FAPRI-UMC Report # 12-04.

[133] CARD. 2009. An Analysis of EPA Renewable Fuel Scenarios with the FAPRI-CARD International Models. Available from: https://www.regulations.gov/document/EPA-HQ-OAR-2017-0655-0093

[134] EPA. 2010. Renewable Fuel Standard program (RFS2) regulatory impact analysis (RIA) Report No.: EPA-420-R–10–006

The version of FASOM/FAPRI used in the EPA's RFS2 analysis has since been refined, making EPA's analysis outdated. This is explicitly acknowledged by EPA throughout Section 4.2.1.2 of the 2022 DRIA, including an acknowledgement on page 118 that "our previously relied on biofuel GHG modeling framework is comparatively old and an updated framework is needed."[135]

Like the 2015 CARB study, the EPA 2010 result is grounded in an accepted model and good processes but falls short by not incorporating the latest updates. These studies both receive a 3/4 score under this example framework where all criteria are weighted the same. However, we must highlight that these analyses have been replaced by studies that meet the 3 criteria EPA and CARB meet but also use better refined models.

### *GREET 2021*

| Criteria | Criteria Met | Evaluation |
|---|---|---|
| Accepted Approach | Yes | GTAP-BIO and GREET are generally accepted approaches |
| Refined Modeling Tools | Yes | Utilizes updated model |
| Complete Data | Yes | Comprehensive geographic and economic scope |
| Transparent Process | Yes | GREET datasets are publicly available and GTAP-BIO is well documented |
| Score: | 4/4 | |

EPA reports four results using ANL's GREET, which uses GTAP-BIO for LUC scenarios. GREET is a trusted tool that is updated annually to incorporate current information.[136] Updates to GTAP-BIO are chronicled in detail and available for review on the developer's website.[137,138,139,140] Members of the public are able to conduct limited replication of GTAP-BIO model runs with a free account.

---

[135] EPA. 2022b. DRIA.
[136] ANL. 2021. Summary of Expansions and Updates in GREET 2021.
[137] GTAP. GTAP Research: Energy. https://www.gtap.agecon.purdue.edu/models/energy/default.asp
[138] Taheripour, F., Birur, D., Hertel, T., & Tyner, W. 2007. Introducing Liquid Biofuels into the GTAP Data Base (GTAP Research Memorandum No. 11). Purdue University, West Lafayette, IN: Global Trade Analysis Project (GTAP). Retrieved from https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=2534
[139] Taheripour, F., & Tyner, W. 2011. Introducing First and Second Generation Biofuels into GTAP Data Base version 7 (GTAP Research Memorandum No. 21). Purdue University, West Lafayette, IN: Global Trade Analysis Project (GTAP). Retrieved from https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=3477
[140] Taheripour, F., Pena-Levano, L., & Tyner, W. 2017b. Introducing first and second generation biofuels into GTAP 9 Data Base (GTAP Research Memorandum No. 29). Purdue University, West Lafayette, IN:

As explained in the 2021 annual documentation, this recent version of GREET has been refined with “updates in both corn farming activities (e.g., corn grain yield, fertilizer/energy inputs) based on the data from the United States Department of Agriculture (USDA) and corn grain ethanol production (e.g., ethanol yield and energy inputs) based on industry biorefinery benchmarking data.”[141]

### *Lark 2022*

| Criteria | Criteria Met | Evaluation |
|---|---|---|
| Accepted Approach | No | Other approach |
| Refined Modeling Tools | No | A new model that has not been tested; conflicts with empirical data |
| Complete Data | No | Only looks at domestic LUC; exclusion of years when corn price trend does not align with ethanol production trend; unsupported baseline |
| Transparent Process | No | Study is not reproducible and all information is not made available |
| Score: | 0/4 | |

In their 2022 paper,[142] Lark et al. present a new approach that has not been tested. The study is not considered complete as it only looks at U.S. domestic LUC. The authors added their partial results to estimates for non-domestic-LUC components generated by EPA, CARB, and GREET.

Further, the authors provide only an incomplete repository of their data and do not provide the models for others to examine and test. As we note in our Biofuels Workshop comments, Lark 2022’s characterization of corn price and demand does not match empirical data, nor does the crop rotation data used match USDA data.[143]

Global Trade Analysis Project (GTAP). Retrieved from https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=5172

[141] ANL. 2021. Summary of Expansions and Updates in GREET 2021.

[142] Lark, T.J., Hendricks, N.P., Smith, A., Pates, N., Spawn-Lee, S.A., Bougie, M., Booth, E.G., Kucharik, C.J. and Gibbs, H.K., 2022. Environmental outcomes of the US renewable fuel standard. Proceedings of the National Academy of Sciences, 119(9), p.e2101084119.

[143] EH&E. 2022a. Comments on the 2022 Workshop on Biofuel Greenhouse Gas Modeling. 1 April 2022. Available within POET’s comment at: https://www.regulations.gov/comment/EPA-HQ-OAR-2021-0921-0047

Aside from failing to meet the criteria above, the Lark et al. study has additional flaws, as noted in our response to the paper,[144] ANL's critiques,[145,146] and USDA's comment on the paper.[147] After extensively evaluating the details throughout a series of comments with the authors of Lark et al., researchers at ANL conclude that "we find that the Lark et al.(a) paper is more problematic than what we initially evaluated to be the case."[148]

EPA itself strongly critiqued the Lark et al. 2022 study in its June 2022 response to comments on the 2020-2022 RFS volumes.[149]

On page 208, EPA comments on a fundamental issue with the paper:

> "Notably, the study does not analyze the impacts of this rulemaking or even the use of renewable fuels during the timeframe for this rule (2020-2022). Rather the study addresses the implementation of the RFS program from 2008-2016. But even for those years, the study simply assumed that the RFS is the cause of all of the historical increases in ethanol production and thereby attributed all of the downstream environmental impacts of ethanol production to the RFS program. However, that assumption is incorrect as it ignores the other factors have contributed to the increase in corn ethanol use and production over time, of which the RFS was only one factor… Indeed, the authors of the study recognize this problem…However, the authors did not go on to assess the extent to which the RFS program as opposed to these other factors contributed to increases in ethanol production or associated environmental impacts. Thus, while the impacts from agricultural practices such as fertilizer use on water and soil quality are observable and measurable, the degree to which those impacts can be causally attributed to the RFS program or this RFS rule is unclear."

EPA's points highlight that Lark's study cannot determine impacts from the RFS, contrary to what the title of Lark et al.'s study may lead readers to believe.

---

144 Alarcon Falconi et al. 2022.
145 Taheripour, F., Mueller, S., Kwon, H., Khanna, M., Emery, I., Copenhaver, K., Wang, M. and CropGrower, L.L.C. 2022b. Comments on "Environmental Outcomes of the US Renewable Fuel Standard".
146 Taheripour, F., Mueller, S., Kwon, H., Khanna, M., Emery, I., Copenhaver, K., Wang, M. and CropGrower, L.L.C., 2022c. Response to comments from Lark et al. regarding Taheripour et al. March 2022 comments on Lark et. al. original PNAS paper.
147 USDA. 2022. Technical Memorandum: Review of Recent PNAS Publication on GHG Impacts of Corn Ethanol. Available from: https://www.usda.gov/sites/default/files/documents/USDA-OCE-Review-of-Lark-2022-For-Submission.pdf
148 Taheripour et al. 2022c.
149 EPA. 2022e. RFS Program: RFS Annual Rules – Response to Comments. Available from: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P101562X.pdf

### *Lee et al. 2021*

| Criteria | Criteria Met | Evaluation |
|---|---|---|
| Accepted Approach | Yes | GREET and GTAP-BIO are generally accepted approaches |
| Refined Modeling Tools | Yes | Utilizes updated GTAP-BIO |
| Complete Data | Yes | Comprehensive geographic and economic scope |
| Transparent Process | Yes | Models are well documented |
| Score: | 4/4 | |

Lee et al. 2021 is another study using recent GREET, with "results from the improved GTAP versions" informing the LUC estimates.[150] As discussed, these updated versions of GREET and GTAP-BIO are key models identified by EPA and have solid documentation and scope. Lee et al.'s study advances estimates by incorporating further refinements to the corn farming and ethanol production processes by analyzing energy efficiency improvements in both sectors.

### *Lewandrowski et al. 2019*

| Criteria | Criteria Met | Evaluation |
|---|---|---|
| Accepted Approach | Yes | FASOM and GTAP-BIO are generally accepted approaches |
| Refined Modeling Tools | Yes | Purpose is to refine EPA's 2010 analysis; incorporates calibrated GTAP-BIO results |
| Complete Data | Yes | Comprehensive geographic and economic scope |
| Transparent Process | Yes | Models are well documented |
| Score: | 3/3 | |

The purpose of Lewandrowski et al.'s paper is to improve EPA's 2010 RFS2 analysis based on more recent information by using GTAP-BIO for the international LUC component.[151] Table 6 of Lewandrowski et al. 2019 shows that LUC emissions estimates are generated by averaging results from multiple runs of GTAP-BIO, including two results from a 2013 GTAP-BIO scenario that have been calibrated to observed data.

### Adding Lewandrowski HEHC Case

We also encourage EPA to give consideration to the high efficiency-high conservation (HEHC) estimate by Lewandrowski et al. The HEHC estimate incorporates opportunities for emissions

[150] Lee et al. 2021.
[151] Lewandrowski et al. 2019.

reductions in the ethanol production process, including prioritizing improved farming technology.[152] This result makes tangible the potential GHG reduction benefits of implementing technological advances and sustainable practices. EPA's Karl Simon included the result from Lewandrowski et al.'s HEHC case the Biofuels Workshop presentation titled "GHG Biofuel Modeling in the U.S.: Summary of the RFS statutory Requirements and Future Needs."[153]

*Scully et al. 2021*

| Criteria | Criteria Met | Evaluation |
|---|---|---|
| Accepted Approach | Yes | GTAP-BIO is a generally accepted model |
| Refined Modeling Tools | Yes | Relies on updated versions of GTAP-BIO |
| Complete Data | Yes | Comprehensive geographic and economic scope |
| Transparent Process | Yes | Study approach is reproducible and GTAP-BIO is well documented |
| Score: | 4/4 | |

EPA reports the central estimate and the low and high values of the range from our Scully et al. analysis. Our paper is a limited topical review which evaluates, filters, and combines components of estimates relevant to U.S. policy to determine a credible range of CI intensity for corn starch ethanol.[154] Our process is outlined in detail within a supplemental table and our review filters for studies using updated versions of the accepted, well-documented GTAP-BIO model. Specifically, the LUC analyses we incorporate into our average, along with our own calculations using GREET, are Taheripour et al. 2017[155] and multiple configurations from USDA 2018.[156] As both of these are robust and recent analyses, we had considered encouraging EPA to include these as individual studies in their review as opposed to keeping them within the Scully et al. 2021 average. However, we recognize concerns that many new iLUC results depend on recent versions of GTAP-BIO (even though, as we show in Figure 1, the downward trend of iLUC estimates is not exclusive to GTAP-BIO). That said, we chose to keep the Taheripour et al. 2017 and USDA 2018 results packaged in the Scully et al. 2021 average, as one compiled

[152] Lewandrowski, J. 2018. Presentation: Assessing the Carbon Footprint of Corn-Based Ethanol. Available from: https://conference.ifas.ufl.edu/ACES/prior/aces18/Presentations/Salon%20K/Thursday/0835%20Lewandrowski%20-%20Y.pdf

[153] Simon, K. 2022. GHG Biofuel Modeling in the U.S.: Summary of the RFS statutory requirements and Future Needs. Available from: https://www.epa.gov/renewable-fuel-standard-program/workshop-biofuel-greenhouse-gas-modeling

[154] Scully et al. 2021a.

[155] Taheripour et al. 2017a.

[156] Flugge, M., Lewandrowski, J., Rosenfeld, J., Boland, C., Hendrickson, T., Jaglo, K., Kolansky, S., Moffroid, K., Riley-Gilbert, M. and Pape, D., 2017. A life-cycle analysis of the greenhouse gas emissions of corn-based ethanol.

representation of recent results using GTAP-BIO, instead of adding additional GTAP-BIO studies to the list.

As we have explained above, the ratings for all studies are provided for illustrative purposes.

### Incorporating Studies that Estimate LUC Only

As described above, the CI of corn ethanol can be divided into multiple categories. Instead of analyzing the full well-to-wheel value, some researchers dig into individual components of the estimate. Allowing the inclusion of studies that focus on one part of the whole is more inclusive of research that has taken a closer look at subsets of our question around the CI of corn ethanol. We propose including studies for which EPA has reviewed the LUC subcomponent, as well as another European study and an empirical study.

For consistency with the process used in Lark et al.'s composite estimates,[157] we will select a GREET value of 46.2 gCO2e/MJ (rounded to 43 gCO2e/MJ) to add to the iLUC component. This aligns well with EPA identifying a range of 40 to 50 gCO2e/MJ for the non-LUC component for the GREET 2021 results.[158] We recommend not adding iLUC values to the EPA 2010 or CARB 2015 or EPA 2010 estimates, which both rely on outdated models.

As noted in the section above, additional studies will still need to be weighted based on their quality.

#### *Adding Studies EPA Considers for LUC Emissions*

Figure 4.2.2.8-1 of EPA's DRIA plots various results for iLUC. Some of these studies would not be candidates to incorporate into the well-to-wheel review:

- CARB 2014,[159] because CARB 2018 already included
- Taheripour 2017,[160] as this value is already included within Scully et al. 2021
- Plevin et al. 2015,[161] since this study aims to estimate and comment on uncertainty, not predict an iLUC value
- ICAO 2021,[162] because the result was built specific to aviation pathways

[157] Lark et al. 2022. Table 2.
[158] EPA. 2022b. DRIA.
[159] CARB. 2014. Detailed Analysis for Indirect Land Use Change. C. A. R. Board. Sacramento, CA: 113.
[160] Taheripour et al. 2017a.
[161] Plevin et al. 2015.
[162] ICAO. 2021. CORSIA Eligible Fuels -- Lifecycle Assessment Methodology. CORSIA Supporting Document. Version 3: 155

The remaining studies, outlined below, could be appropriate to consider in EPA's range.

### Carriquiry et al. 2019

| Criteria | Criteria Met | Evaluation |
|---|---|---|
| Accepted Approach | Yes | FAPRI-CARD is a generally accepted model |
| Refined Modeling Tools | Yes | Uses updated FAPRI-CARD with improved data |
| Complete Data | Yes | Comprehensive geographic and economic scope |
| Transparent Process | Yes | Model adjustments are well documented |
| Score: | 4/4 | |

As described in Part I, Carriquiry et al. 2019 uses updated version of FAPRI and calibrates the model to empirical data. The lineage of the FAPRI-CARD version used is well-documented by the papers this study builds on, such as Dumortier et al. 2011.[163]

### Laborde 2014

| Criteria | Criteria Met | Evaluation |
|---|---|---|
| Accepted Approach | Yes | MIRAGE is a generally accepted model |
| Refined Modeling Tools | Yes | Uses improved MIRAGE model |
| Complete Data | Yes | Comprehensive geographic and economic scope |
| Transparent Process | Yes | Model updates are well documented |
| Score: | 4/4 | |

EPA includes Laborde 2014 in Figure 4.2.2.8-3 of the 2022 DRIA when discussing estimates for cropland area change.[164] Laborde uses the MIRAGE model to estimate economy-wide global impacts.

As discussed in Part I, Laborde tunes the model based on information about yield and crop replacement. When EPA retrieved cropland area values from Laborde 2014, the Agency selected the iteration that incorporated all updates but did not freeze food consumption,[165] which we agree is an appropriate selection.

[163] Dumortier et al. 2011.
[164] EPA. 2022b. DRIA.
[165] EPA 2022 Notes on Literature Review of Transportation Fuel Greenhouse Gas (GHG) Lifecycle Analysis (LCA)

We consider the MIRAGE model an acceptable approach as the MIRAGE results provide the scientific basis for European Commission policy on GHG emissions from iLUC associated with biofuels from corn and cereal grains.[166,167]

Developers of the MIRAGE model have recorded progress made throughout model updates.[168,169,170]

### *Adding Another European Study*

#### Valin et al. 2015

| Criteria | Criteria Met | Evaluation |
|---|---|---|
| Accepted Approach | Yes | GLOBIOM is a generally accepted model |
| Refined Modeling Tools | Yes | Uses improved GLOBIOM model |
| Complete Data | Yes | Comprehensive geographic and economic scope |
| Transparent Process | Yes | Model updates are well documented |
| Score: | | |

Valin et al. 2015 uses GLOBIOM to estimate global impacts on agriculture, livestock, forestry, and bioenergy sectors. GLOBIOM is one of the key models EPA identifies in Table 4.2.2.7-1 of the 2022 DRIA.[171]

Valin et al.'s paper describes updates to this edition of the model, such as how biofuel production projects are calibrated to statistics (page 18) and crop prices from GLOBIOM are calibrated to observed prices (page 26).[172]

---

166 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.

167 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.

168 Decreux, Y. and Valin, H., 2007. MIRAGE, updated version of the model for trade policy analysis: focus on agriculture and dynamics (No. 1423-2016-117757).

169 Laborde, D. and Valin, H., 2012. Modeling land-use changes in a global CGE: assessing the EU biofuel mandates with the MIRAGE-BioF model. Climate Change Economics, 3(03), p.1250017.

170 Laborde 2011.

171 EPA. 2022b. DRIA.

172 Valin, H., Peters, D., Van den Berg, M., Frank, S., Havlik, P., Forsell, N., Hamelinck, C., Pirker, J., Mosnier, A., Balkovic, J. and Schmidt, E., 2015. The land use change impact of biofuels consumed in the EU: Quantification of area and greenhouse gas impacts.

Detailed updates to GLOBIOM have been documented by researchers, including a 2018 report by the International Institute for Applied Systems Analysis that summarizes the 2015 version used by Valin et al.[173,174,175]

*Adding Another Empirical Study*

### Overmars et al. 2015

| Criteria | Criteria Met | Evaluation |
|---|---|---|
| Accepted Approach | No | Other approach |
| Refined Modeling Tools | No | Uses simplified spreadsheet calculations instead of economic modeling |
| Complete Data | Yes | Historical data has a comprehensive geographic and economic scope, though economic tools are crude |
| Transparent Process | Yes | Approach emphasizes reproducibility and publicly available data |
| Score: | 2/4 | |

Woltjer identifies iLUC studies that rely on various approaches for a European Commission publication.[176] This review shows not all empirical studies are showing higher results. For example, Overmars et al. 2015 use historical data to estimate iLUC impacts from corn starch ethanol and other biofuels.[177] Overmars et al. 2015 report compares results using two different emissions factor models (CSAM and IMAGE) and two different allocation methods. Results varied based on the selected emissions factors but did change when switching allocation methods.

This study does improve the work done in Overmars et al. 2011[178] but still uses an oversimplified spreadsheet approach. Even the authors note that "our method is less rigorous

---

[173] Valin, H., Havlík, P., Forsell, N., Frank, S., Mosnier, A., Peters, D., Hamelinck, C., Spöttle, M. and van den Berg, M., 2013. Description of the GLOBIOM (IIASA) model and comparison with the MIRAGE-BioF (IFPRI) model. Crops, 8(3.1), p.10.

[174] Valin, H., Frank, S., Pirker, J., Mosnier, A., Forsell, N., Havlik, P., Peters, D. and Hamelinck, C., 2014. Improvements to GLOBIOM for modelling of biofuels indirect land use change. ILUC Quantification Consortium: Utrecht, The Netherland.

[175] International Institute for Applied Systems Analysis. 2018. GLOBIOM documentation.

[176] Woltjer et al. 2017..

[177] Overmars, K., Edwards, R., Padella, M., Prins, A.G., Marelli, L. and Consultancy, K.O., 2015. Estimates of indirect land use change from biofuels based on historical data. JRC Science and Policy Report, Ref. no. EUR, 26819.

[178] Overmars, K.P., Stehfest, E., Ros, J.P. and Prins, A.G., 2011. Indirect land use change emissions related to EU biofuel consumption: an analysis based on historical data. Environmental Science & Policy, 14(3), pp.248-257.

than economic models and does not pretend to replace economic models in ILUC estimates."[179] Albeit the noted shortcomings, Overmars et al. 2015 does capture economic effects across 11 global regions. Reproducibility is a tenet of this paper, which uses publicly available data and describes steps in detail.

### Reviewing the Refined Range

After assigning a score to each study, we review the suite of results with a color gradient assigned to denote the reliability of the study. The lowest of our example scores are shown in yellow (0/4) and light orange (1/4), while the highest example scores are shown in dark orange (3/4) and red (4/4). Again, these scores are an example of an approach to rating studies that we encourage EPA to consider.

We first share the list with the inclusion of results from additional studies that we recommend EPA add to its literature review, where the new analyses are highlighted in blue. Our scoring scale shows that the studies meeting all criteria (receiving the highest score of 4/4) represent a range of 27 to 67 gCO2e/MJ, on the lower end of EPA's full range. The average of that range (52 gCO2e/MJ) is in line with the central estimate from our Scully et al. 2021 study (51 gCO2e/MJ).

Also, the studies meeting 3 of 4 criteria are all from the CARB 2018 and EPA 2010 analysis, which were grounded in good techniques but are now simply outdated. This reinforces our observation that as quality studies are refined and improved, the CI estimates they produce for corn ethanol converge on lower values. Note that this example assessment equally weights all evaluation criteria, which is why the CARB 2018 and EPA 2010 results score relatively well even though they have been superseded.

[179] Overmars et al. 2015.

| Table 7 Sample Evaluation of Well-to-Wheel (WTW) Corn Starch Ethanol Carbon Intensity Results for Studies in EPA's 2022 DRIA Plus Additional Recommended Studies | | |
|---|---|---|
| **Analysis** | **WTW (gCO2e/MJ)** | **Score** |
| Lark et al. (2022)/Other/RFS2 RIA | 116 | 0/4 |
| Brandão (2022) | 105 | 0/4 |
| Lark et al. (2022)/Other/CA-LCFS | 105 | 0/4 |
| CARB (2018)/GTAP-BIO+AEZ-EF/Dry Mill/High LUC | 94 | 3/4 |
| RFS2 rule (2010)/FASOM-FAPRI/NG Dry DDGS/High LUC | 91 | 3/4 |
| Lark et al. (2022)/Other/GREET | 90 | 0/4 |
| CARB (2018)/GTAP-BIO+AEZ-EF/Dry Mill/Mean LUC | 77 | 3/4 |
| RFS2 rule (2010)/FASOM-FAPRI/2022 Avg NG Dry Mill/Mean LUC | 73 | 3/4 |
| BEIOM (2021)/Avg. Dry Mill | 69 | 1/4 |
| CARB (2018)/GTAP-BIO+AEZ-EF/Dry Mill/Low LUC | 68 | 3/4 |
| Carriquiry (2019)/FAPRI-CARD/High + GREET | 67 | 4/4 |
| Scully et al. (2021)/GTAP-BIO+CCLUB/High LUC | 65 | 4/4 |
| GREET (2021)/GTAP-BIO+CCLUB/NG Dry Mill DDGS | 57 | 4/4 |
| Valin (2015)/GLOBIOM + GREET | 57 | 4/4 |
| GREET (2021)/GTAP-BIO+CCLUB/Avg Plant | 56 | 4/4 |
| Carriquiry (2019)/FAPRI-CARD /Central + GREET | 56 | 4/4 |
| Overmars(2015)/CSAM + GREET | 56 | 2/4 |
| Laborde(2014)/MIRAGE + GREET | 55 | 4/4 |
| GREET (2021)/GTAP-BIO+CCLUB/Gen 1.5 w/ DCO | 53 | 4/4 |
| Carriquiry (2019)/FAPRI-CARD /Low + GREET | 53 | 4/4 |
| Lewandrowski et al. (2019)/FASOM+GTAP-BIO/2022 BAU | 52 | 4/4 |
| Scully et al. (2021)/GTAP-BIO+CCLUB/Central LUC | 51 | 4/4 |
| Overmars(2015)/IMAGE + GREET | 49 | 2/4 |
| RFS2 rule (2010)/FASOM-FAPRI/Adv. NG Dry Mill/Low LUC | 49 | 3/4 |
| GREET (2021)/GTAP-BIO+CCLUB/NG Dry Mill WDGS | 47 | 4/4 |
| Lee et al. (2021)/GTAP-BIO+CCLUB/2019 | 45 | 4/4 |
| Scully et al. (2021)/GTAP-BIO+CCLUB/Low LUC | 38 | 4/4 |
| Lewandrowski et al. (2019)/FASOM+GTAP-BIO/HEHC | 26 | 4/4 |

Even when we remove the additional studies our team recommends adding, the outcome presented by the chart is very clear: studies that use current and complete data are concentrated in the lower half of the range. With this narrower lens, the studies meeting all criteria (a score of 4/4) represent a range of 38 to 65 gCO2e/MJ with an average of 52 gCO2e/MJ, which aligns with our best central estimate of 51 gCO2e/MJ.

**Table 8** Sample Evaluation of Well-to-Wheel (WTW) Corn Starch Ethanol Carbon Intensity Results for Studies in EPA's 2022 DRIA

| Analysis | WTW (gCO2e/MJ) | Score |
|---|---|---|
| Lark et al. (2022)/Other/RFS2 RIA | 116 | 0/4 |
| Brandão (2022) | 105 | 0/4 |
| Lark et al. (2022)/Other/CA-LCFS | 105 | 0/4 |
| CARB (2018)/GTAP-BIO+AEZ-EF/Dry Mill/High LUC | 94 | 3/4 |
| RFS2 rule (2010)/FASOM-FAPRI/NG Dry DDGS/High LUC | 91 | 3/4 |
| Lark et al. (2022)/Other/GREET | 90 | 0/4 |
| CARB (2018)/GTAP-BIO+AEZ-EF/Dry Mill/Mean LUC | 77 | 3/4 |
| RFS2 rule (2010)/FASOM-FAPRI/2022 Avg NG Dry Mill/Mean LUC | 73 | 3/4 |
| BEIOM (2021)/Avg. Dry Mill | 69 | 1/4 |
| CARB (2018)/GTAP-BIO+AEZ-EF/Dry Mill/Low LUC | 68 | 3/4 |
| Scully et al. (2021)/GTAP-BIO+CCLUB/High LUC | 65 | 4/4 |
| GREET (2021)/GTAP-BIO+CCLUB/NG Dry Mill DDGS | 57 | 4/4 |
| GREET (2021)/GTAP-BIO+CCLUB/Avg Plant | 56 | 4/4 |
| GREET (2021)/GTAP-BIO+CCLUB/Gen 1.5 w/ DCO | 53 | 4/4 |
| Lewandrowski et al. (2019)/FASOM+GTAP-BIO/2022 BAU | 52 | 4/4 |
| Scully et al. (2021)/GTAP-BIO+CCLUB/Central LUC | 51 | 4/4 |
| RFS2 rule (2010)/FASOM-FAPRI/Adv. NG Dry Mill/Low LUC | 49 | 3/4 |
| GREET (2021)/GTAP-BIO+CCLUB/NG Dry Mill WDGS | 47 | 4/4 |
| Lee et al. (2021)/GTAP-BIO+CCLUB/2019 | 45 | 4/4 |
| Scully et al. (2021)/GTAP-BIO+CCLUB/Low LUC | 38 | 4/4 |

Both of these tables assert that, in general, more reliable studies present lower CI values and, therefore, should be given more consideration by EPA.

## INFORMING THE FINAL RULE

We now transition to another call from EPA:

> EPA: We also invite comment on how this information [referring to EPA's review of CI estimates] may be used to inform the final rule.[180]

Given the presence of uncertainty, where values are true but unknown, EPA should use the best available science to determine an improved estimate for the CI of corn ethanol and use this updated value to inform the final rule. As our findings in the prior sections have shown, the best

[180] EPA. 2022a.

available science produces lower CI estimates corn starch ethanol than older analyses. **This is consistent with our conclusion in Scully et al. 2021 that corn starch ethanol represents an approximately 46%reduction in GHG emissions relative to gasoline**.[181]

Reliance on the best available science for the CI of corn ethanol provides for more accurate characterization of GHG emissions for the U.S. transportation sector than continued use of EPA's 2010 estimate, as proposed by EPA in its 2022 DRIA. The best available science indicates that the 2022 DRIA overestimates the CI of corn ethanol and transportation sector GHG emissions. These same overestimates result in underestimates of U.S. progress toward decarbonization and attainment of national and international climate goals, such as the Paris Agreement. These goals have relatively near-term science-based target dates including a 43% reduction in emissions by 2030 and net zero emissions by 2050.[182] Continued reliance on an inaccurate CI for corn ethanol will likely hinder the ability of EPA and others to prioritize investment and policy into technologies that can effectively reduce GHG emissions over those timeframes. It is thus imperative that EPA incorporate the best available science on the CI of corn ethanol into its analyses.

## IMPACTS OVER TIME

We continue with another prompt from EPA:

| |
|---|
| EPA: Since models treat time differently (e.g., different time steps, static versus dynamic models), we invite comment on the most appropriate way to handle the GHG impacts of biofuels over time.[183] |

We find two ways to consider this question: one option lies in the details of existing models and the other looks forward over time into the future.

For the first prompt, we agree with EPA's preference of selecting a 30-year amortization period for LUC, as reasoned in Section 4.2.3.1 of the DRIA (page 167).[184] EPA begins incorporating this consideration in DRIA Table 4.2.3.13-2 (page 194) by presenting the range of high and low values of the 30-year scenarios from the 2010 RFS2 estimates. We encourage EPA to calculate rough estimates of 30-year values for the other results included in the CI range from the literature review. To do this, EPA would multiply each estimate by its current amortization period then

[181] Scully et al. 2021a.

[183] EPA. 2022a.

[184] EPA. 2022b. DRIA.

divide that value by 30. EPA can then use these scaled results to preliminarily present an updated range that reasonably reflects a consistent amortization period of 30 years.

The second interpretation asks what we think EPA should do now in terms of looking forward in time at future emissions. EPA's 2010 analysis included forecasting of what would be reasonably expected of industries (including farming and production processes) in the foreseeable future. EPA is repeating that process of looking ahead now by considering models that look into the future with a 20 or 30-year time horizon. We have seen, however, that much has changed since 2010 with respect to climate mitigation measures that impact the lifecycle emissions of corn ethanol. Not all technical advances in efficiency would have been predicted and captured in the 2010 estimates but, if included, these would have reduced estimates for the CI of corn ethanol. Current trends in climate law and policy indicate that decarbonization of the ethanol supply chain will only continue in the future.

In fact, there has been significant investment in GHG mitigation and emissions reduction technologies that EPA did not predict in 2010. And there have been significant advances in areas such as carbon dioxide removal technology and carbon capture utilization and geological sequestration. These improvements all further reduce the carbon emissions from corn starch ethanol and will continue being implemented and enhanced as the decades progress.

As another example of programs implemented, California's Low Carbon Fuel Standard (LCFS) employs a credit system that encourages biorefineries to reduce the CI of their plant's products and incentivizes fuel blenders to select options with a lower CI.[185,186] A 2021 review of LCFSs enacted in California, Oregon, and British Columbia concluded that each of these jurisdictions has consistently met their annual carbon intensity reduction goals for the program.[187,188]

We anticipate that between the time researchers are now making estimates and when the amortized dates arrive, technological advances will continue to bring down emissions for elements of the corn starch ethanol lifecycle. We encourage EPA to incorporate potential technology improvements into the new analysis the Agency will conduct. One such way to do so would be to adjust data inputs, either in the primary analysis or a sensitivity analysis, to consider

[185] Liu, X., Kwon, H., Northrup, D. and Wang, M., 2020. Shifting agricultural practices to produce sustainable, low carbon intensity feedstocks for biofuel production. Environmental Research Letters, 15(8), p.084014.

[186] CARB. 2020. Slides: LCFS Basics with Notes. https://ww2.arb.ca.gov/sites/default/files/2020-09/basics-notes.pdf

[187] Mazzone, D., Witcover, J. and Murphy, C., 2021. Multijurisdictional Status Review of Low Carbon Fuel Standards, 2010–2020 Q2: California, Oregon, and British Columbia.

[188] Axsen, J. and Wolinetz, M., 2023. What does a low-carbon fuel standard contribute to a policy mix? An interdisciplinary review of evidence and research gaps. Transport Policy.

more aggressive carbon reduction strategies and technologies, such as how Lewandrowski et al. 2019 incorporate an HEHC estimate.[189]

## NEW RESEARCH

We now move to the final invitation from EPA:

| |
|---|
| EPA: We also request comment on how we can incorporate new research that examines the effectiveness of the RFS program in mitigating GHG emissions.[190] |

We recommend EPA review the IEA report mentioned in Part I, which shows that empirical data does not indicate the association of iLUC with biofuel demand as suggested by older, unrefined agroeconomic models.[191] Instead, if biofuel production is not linked to iLUC and thus iLUC is not added to the overall CI value, then the resulting lower estimates for overall CI would be closer to the lower results produced from updated models.

An additional topic to address in this rulemaking or thereafter is determining an updated estimate for the carbon impact of gasoline. Though EPA does briefly review CI estimates for gasoline in section 4.2.3.2 of the DRIA, there has been, in general, less attention on the indirect impacts of gasoline production.[192,193] Better understanding the full weight of GHG implications assigned to petroleum will allow the carbon reductions offered by biofuels like corn starch ethanol to become even more apparent.

We would also like to comment on a December 2202 Reuters article that discusses the illustrative scenario presented in Section 4.2.4 of the DRIA.[194,195] The article headline and its first few paragraphs misrepresent EPA's findings by describing the outcome of only a segment of a cumulative assessment. While the intermediate values presented by Reuters do match the numbers reported in the DRIA, it is misleading to extract a portion of a 30-year analysis. Later in

---

[189] Lewandrowski et al. 2019.
[190] EPA. 2022a.
[191] IEA Bioenergy. 2022.
[192] Martin, E.W., Chester, M.V. and Vergara, S.E., 2015. Attributional and consequential life-cycle assessment in biofuels: a review of recent literature in the context of system boundaries. Current Sustainable/Renewable Energy Reports, 2(3), pp.82-89.
[193] Dale, B.E. and Kim, S., 2014. Can the Predictions of Consequential Life Cycle Assessment Be Tested in the Real World? Comment on "Using Attributional Life Cycle Assessment to Estimate Climate-Change Mitigation...". Journal of Industrial Ecology, 18(3), pp.466-467.
[194] Reuters. 2022. U.S. biofuels proposal would lift near-term greenhouse gas emissions, EPA says. https://www.reuters.com/business/environment/us-biofuels-proposal-would-lift-near-term-greenhouse-gas-emissions-epa-says-2022-12-15/ 15 December 2022.
[195] EPA. 2022b. DRIA.

the article, Reuters quotes an email from EPA stating that it is "inappropriate to truncate the analysis after 3 years,"[196] even though this is exactly what Reuters does above.

Further, the DRIA explains on pages 193 and 194 that the illustrative scenario in the 2022 DRIA is based only on GHG impacts calculated in EPA's old 2010 RFS2 analysis. Even though EPA presents the range of their recent literature review in Table 4.2.3.13-1 and discusses some of this new science in detail, these values are not considered in the illustrative scenario. For corn starch ethanol, the range considered in the illustrative scenario is 49 to 91 gCO2e/MJ when amortized to 30 years, as shown in DRIA Table 4.2.3.13-2. This range does not incorporate new science and adjustments made over the past decade. As shown above, the best available recent science converges on a range lower than that produced by older, unrefined studies.

With that disclaimer in mind, we can look again at the DRIA's full 30-year evaluation across all biofuels. Totaling the values presented in DRIA Tables 4.1.4-9 and 4.1.4-13 results in an estimated GHG reduction of 128.2 million to 1.2 billion metric tons of CO2 over 30 years from using the proposed biofuel standards. The low estimate uses the low end of the petroleum gasoline baseline (84 gCO2e/MJ) and the high end of the CI for each biofuel, while the high estimate uses a high petroleum gasoline baseline (98 gCO2e/MJ) and the low CI for each biofuel. Both the low and high scenarios predict an GHG overall reduction over 30 years when using the proposed standards. Zooming in on just corn ethanol, EPA's estimated impacts over 30 years spread from a reduction of 99 million metric tons of CO2 to an increase of 13.8 million metric tons of CO2, with a central estimate of a reduction of 42.6 million metric tons of CO2. Using a more appropriate value for the CI of corn ethanol would better reflect its GHG reduction benefits in an illustrative scenario.

[196] Reuters. 2022.

## PART III: ADDITIONAL AIR QUALITY BENEFTS OF CORN STARCH ETHANOL

With the above sections focusing on the GHG effects of corn starch ethanol, our final section looks at the non-GHG emissions in the context of health effects and environmental justice.

In Part III, we summarize the best available science on the relationship between ethanol, tailpipe emissions, and health. Our detailed comments on those topics are presented following the summary. Our comments are largely based upon our research that has resulted in two peer-reviewed publications: a comprehensive assessment of the impacts of corn ethanol fuel blends on tailpipe emissions of regulated pollutants and of air toxics.[197,198]

### CORN ETHANOL FUEL BLENDS

Most gasoline used for light-duty vehicles in the US is E10, which contains a blend of 10% (by volume) ethanol with a gasoline blend stock. Ethanol is used as a fuel additive in gasoline to boost octane without the harmful impacts posed by previous fuel additives such as methyl tert-butyl ether (MTBE) and lead. Octane rating reflects the ability of a fuel to avoid premature or auto ignition.[199] Aromatics, such as benzene, toluene, ethylbenzene, and BTEX also boost gasoline octane, but they are considered hazardous air pollutants.[200] The high-octane rating of ethanol thus also enables reduction of aromatics in the fuel.[201,202,203] In our recent study, we showed that aromatic levels decrease by approximately 7% by volume for each 10% by volume increase in ethanol content.[204] These findings are consistent with market fuel studies and with octane blending studies[205,206,207,208] and have implications for tailpipe emissions of light-duty vehicles, as will be discussed in the next section.

[197] Kazemiparkouhi et al. 2022a.
[198] Kazemiparkouhi et al. 2022b.
[199] Anderson JE, DiCicco DM, Ginder JM, Kramer U, Leone TG, Raney-Pablo HE, Wallington TJ. 2012. High octane number ethanol–gasoline blends: Quantifying the potential benefits in the United States. Fuel, 97: 585-94.
[200] Clark, N.N., McKain Jr., D.L., Klein, T., Higgins, T.S. 2021. Quantification of gasoline-ethanol blend emissions effects. Journal of the Air & Waste Management Association, 71: 3-22.
[201] Clark et al. 2021.
[202] Kazemiparkouhi et al. 2022a.
[203] EPA. 2017. Fuel Trends Report: Gasoline 2006-2016.
[204] Kazemiparkouhi et al. 2022a.
[205] Anderson JE, Kramer U, Mueller SA, Wallington TJ. 2010. Octane Numbers of Ethanol− and Methanol−Gasoline Blends Estimated from Molar Concentrations. Energy & Fuels, 24, 6576-6585.
[206] Anderson et al. 2012.
[207] Stratiev D, Nikolaychuk E, Shishkova I, Bonchev I, Marinov I, Dinkov R, Yordanov D, Tankov I, Mitkova M. 2017. Evaluation of accuracy of literature gasoline blending models to predict octane numbers of gasoline blends. Petroleum Science and Technology, 35, 1146-1153.
[208] EPA. 2017. Fuel Trends Report: Gasoline 2006-2016.

## CORN ETHANOL FUEL BLENDS AND TAILPIPE EMISSIONS

When reviewing the literature, it is important to select studies that reflect a vehicle fleet composition that is representative of current conditions. Light-duty vehicle fuel economy has increased by 32% in the US since vehicle model year 2004,[209] and emissions have decreased. For light-duty vehicles, the EPA lowered the permissible emissions of CO, NOx, non-methane organic gases (NMOG), PM, and formaldehyde from Tier 1 standards to Tier 2 standards (which took full effect in 2004), with additional reductions (Tier 3 standards) being phased in since 2017.[210] Thus, all vehicles on the road in the US prior to 2008 were held to Tier 1 (highest permissible emissions) and Tier 2 standards, while nearly all vehicles today are held to Tier 2 and Tier 3 (lowest permissible emissions) standards.

To better reflect current ethanol impacts on vehicle emissions, we reviewed over 95 studies that characterized emissions from light-duty vehicles powered by E0 and ethanol blends, focusing on Tier 2 and higher vehicles. These studies assessed pollutant emissions from a wide variety of common vehicle models, engine types, and engine operating conditions (e.g., cold start, hot running, and hot start[211]) and were conducted by both commercial and public organizations. We also draw from our own two recent studies, which are the first large-scale analyses of data from light-duty vehicle emissions studies to examine real-world impacts of ethanol-blended fuels on air pollutant emissions.[212][213] We summarized the results of those studies and discussed implications for air quality and public health in our August 2022 white paper.[214]

Emission studies of ethanol fuel blends show that tailpipe pollutant emissions vary with ethanol and aromatic content. Higher ethanol content in fuels was associated with lower emissions of key health-relevant pollutants, PM, BC, PN, and BTEX, while fuels with higher aromatic fuel

---

209 Hula A, Maguire A, Bunker A, Rojeck T, Harrison S. 2021. The 2021 EPA Automotive Trends Report: Greenhouse Gas Emissions, Fuel Economy, and Technology since 1975. EPA-420-R-21-00. Washington (DC): United States Environmental Protection Agency.

210 EPA. 2022f. Light Duty Vehicle Emissions.

211 Hot start or hot running conditions occur when an engine is started or is running at regular operating temperatures (i.e., during or soon after fully warmed-up operation). Cold start conditions occur when an engine is started at temperatures below regular operating conditions. Engine operating conditions impact tailpipe emissions, with cold start emissions accounting for a substantial portion of tailpipe emissions (Reiter and Kockelman 2016).

212 Kazemiparkouhi et al. 2022a.

213 Kazemiparkouhi et al. 2022b.

214 Kazemiparkouhi, F., MacIntosh, D., Suh, H., Clark, N. 2022c. Potential Air Quality and Public Health Benefits of Real-World Ethanol Fuels.

content generally showed the opposite pattern.[215,216,217,218,219,220,221,222,223,224,225,226] In our papers, we observed similar patterns of decreasing PM, BTEX, BC, and PN with increasing ethanol content.[227] Primary PM emissions, for example, decreased by 15 – 18% on average for each 10% increase in ethanol content under cold-start conditions.[228] Cold start PM emissions have consistently been shown to account for a substantial portion of all direct tailpipe PM emissions.[229,230] A 2022 CARB study that assessed the impact of E15 (splash-blended from E10) on air pollutant emissions for late model year vehicles (2016 – 2021) found that switching from E10 to E15 reduced PM emissions by 18%, with cold-start emissions being reduced by 17%.[231]

Ethanol blended fuels were also consistently shown to emit lower amounts of CO, THC, and non-methane hydrocarbons (NMHC) as compared to non-ethanol blended fuels, consistent with

---

[215] Clark et al. 2021.

[216] Karavalakis G. 2018. Impacts of Aromatics and Ethanol Content on Exhaust Emissions from Gasoline Direct Injection (Gdi) Vehicles. University of California, Riverside.

[217] Karavalakis G, Short D, Vu D, Villela M, Russell R, Jung H, Asa-Awuku A, Durbin T. Regulated Emissions, Air Toxics, and Particle Emissions from Si-Di Light-Duty Vehicles Operating on Different Iso-Butanol and Ethanol Blends. SAE International Journal of Fuels and Lubricants 7, no. 1 (2014): 183-99.

[218] Kumar R, Chaurasia O. 2019. A Review on Performance and Emissions of Compression Ignition Engine Fueled with Ethanol-diesel Blend. Journal Européen des Systèmes Automatisés, 52: 205-14.

[219] Liang X, Zhang S, Wu X, Guo X, Han L, Liu H, Wu Y, Hao J. 2020. Air quality and health impacts from using ethanol blended gasoline fuels in China. Atmospheric Environment, 228.

[220] Myung C-L, Choi K, Cho J, Kim K, Baek S, Lim Y, Park S. 2020. Evaluation of regulated, particulate, and BTEX emissions inventories from a gasoline direct injection passenger car with various ethanol blended fuels under urban and rural driving cycles in Korea. Fuel, 262.

[221] Roth P, Yang J, Peng W, Cocker DR, Durbin TD, Asa-Awuku A, Karavalakis G. 2020. Intermediate and high ethanol blends reduce secondary organic aerosol formation from gasoline direct injection vehicles. Atmospheric Environment, 220.

[222] Sakai S, Rothamer D. 2019. Impact of ethanol blending on particulate emissions from a spark-ignition direct-injection engine. Fuel, 236: 1548-58.

[223] Schuchmann B, Crawford R. 2019. Alternative Oxygenate Effects on Emissions. Alpharetta, GA (United States).

[224] Yang J, Roth P, Durbin T, Karavalakis G. 2019a. Impacts of gasoline aromatic and ethanol levels on the emissions from GDI vehicles: Part 1. Influence on regulated and gaseous toxic pollutants. Fuel, 252: 799-811.

[225] Yang J, Roth P, Zhu H, Durbin TD, Karavalakis G. 2019b. Impacts of gasoline aromatic and ethanol levels on the emissions from GDI vehicles: Part 2. Influence on particulate matter, black carbon, and nanoparticle emissions. Fuel, 252:812-820.

[226] Zheng X, Wu X, He L, Guo X, Wu Y. 2019. Black Carbon Emissions from Light-duty Passenger Vehicles Using Ethanol Blended Gasoline Fuels. Aerosol and Air Quality Research, 19: 1645-54.

[227] Kazemiparkouhi et al. 2022a, 2022b.

[228] Kazemiparkouhi et al. 2022c.

[229] Darlington TL, Kahlbaum D, Van Hulzen S, Furey RL. 2016. Analysis of EPAct Emission Data Using T70 as an Additional Predictor of PM Emissions from Tier 2 Gasoline Vehicles.

[230] EPA. 2013. Assessing the Effect of Five Gasoline Properties on Exhaust Emissions from Light-Duty Vehicles Certified to Tier 2 Standards: Analysis of Data from EPAct Phase 3 (EPAct/V2/E-89): Final Report. EPA-420-R-13-002 ed.: Assessment and Standards Division Office of Transportation and Air Quality U.S. Environmental Protection Agency.

[231] Karavalakis G, Durbin TD, Tang T. 2022 Comparison of Exhaust Emissions Between E10 CaRFG and Splash Blended E15. Final Report. Riverside, CA: California Air Resources Board (CARB), Growth Energy Inc./Renewable Fuels Association (RFA), and USCAR.

their cleaner combustion and higher amounts of acetaldehyde, which is produced directly from ethanol combustion.[232,233,234,235,236,237,238,239,240,241,242,243,244]

Less consistent was the impact of ethanol fuel blends on emissions of NOx, for which trends varied by study perhaps due to their reactivity and sensitivity to other species in the emission effluent. However, our recent study of low to mid ethanol fuel blends (E0 to E30) and CARB's 2022 study show that NOx did not change with increasing ethanol content. Acrolein emissions also did not change with increasing ethanol content, while formaldehyde emissions showed little to no significant change.[245]

To the extent that ethanol is a substitute for octane-enhancing aromatics in fuel (as discussed in the Corn Ethanol Fuel Blends section), our review of the literature and results from our emission studies demonstrate that higher ethanol fuel blends reduce emission for PM, BTEX, 1-3 butadiene, BC, and PN with no concomitant increase in emissions for CO, THC, NOx, or acrolein. A presentation by researchers at the University of California, Riverside who contributed to the CARB 2022 report further predict that "the introduction of E15 will likely reduce air toxics from current technology vehicles."[246] Based on the currently available data, we agree with this expectation that E15 will reduce local pollutants when compared with E10 and E0.

---

[232] Badrawada IGG, Susastriawan AAP. 2019. Influence of ethanol–gasoline blend on performance and emission of four-stroke spark ignition motorcycle. Clean Technologies and Environmental Policy, 21: 1891-96.
[233] Clark et al. 2021.
[234] Gunst 2013.
[235] Karavalakis 2018.
[236] Karavalakis G, Durbin TD, Shrivastava M, Zheng Z, Villela M, Jung H. 2012. Impacts of ethanol fuel level on emissions of regulated and unregulated pollutants from a fleet of gasoline light-duty vehicles. Fuel, 93: 549-58.
[237] Karavalakis et al. 2022.
[238] Kazemiparkouhi et al. 2022c.
[239] Mourad M, Mahmoud K. 2019. Investigation into SI engine performance characteristics and emissions fuelled with ethanol/butanol-gasoline blends. Renewable Energy, 143: 762-71.
[240] Oak Ridge National Laboratory (ORNL), National Renewable Energy Laboratory (NREL), and Argonne National Laboratory (ANL). 2016. Summary of High-Octane, Mid-Level Ethanol Blends Study. In.: Oak Ridge National Laboratory.
[241] National Renewable Energy Laboratory (NREL). 2013. "Statistical Analysis of the Phase 3 Emissions Data Collected in the Epact/V2/E89 Program." edited by National Renewable Energy Laboratory. Golden, CO. New York State Climate Action Council Draft Scoping Plan (DSP). 2021.
[242] Roso VR, Souza Alvarenga Santos ND, Castilla Alvarez CE, Rodrigues Filho FA, Pacheco Pujatti FJ, Molina Valle R. 2019. Effects of mixture enleanment in combustion and emission parameters using a flex-fuel engine with ethanol and gasoline. Applied Thermal Engineering, 153: 463-72.
[243] Theiss T. 2016. Summary of High-Octane Mid-Level Ethanol Blends Study.
[244] Wayson. 2016. Evaluation of Ethanol Fuel Blends in Moves2014 Model. Renewable Fuels Association.
[245] Kazemiparkouhi et al. 2022a, 2022b, 2022c; Karavalakis et al. 2022.
[246] Tang T, Durbin TD, Johnson KC, Karavalakis G. 2022. Aiming at the increase of California's ethanol 'blend wall': gaseous and particulate emissions evaluation from a fleet of GDI and PFI vehicles operated on E10 and E15 fuels. Presentation.

## CORN ETHANOL FUEL BLENDS AND AIR QUALITY

The estimated reductions in air pollutant emissions discussed above, particularly of PM, indicate that increasing ethanol content will result in improvements in air quality. We reviewed over 45 studies that examined issues related to ethanol blended fuel impacts on air quality and air pollutant exposures, with many of these studies conducted outside the US. Results from these studies were generally consistent with those from emissions testing studies. Numerous studies have shown that lower PM emissions result in lower ambient PM concentrations and exposures.[247,248] A study in Wisconsin found lower levels of CO after introduction of E10[249] were consistent with emission testing data that showed a reduction in CO emissions with higher ethanol content (as discussed in the prior section). Similarly, an analysis of US-wide air quality measurements found that reductions of targeted aromatics in fuel were associated with lower summertime ozone levels.[250]

Less well-studied is the impact of ethanol-based fuels on acetaldehyde and formaldehyde concentrations; however, atmospheric measurements indicate that use of E10 and other ethanol blends do not increase concentrations of acetaldehyde and formaldehyde above background levels in ambient air, indicating that emissions from other sources are larger than from light-duty vehicles.[251,252]

It is worth noting that we did not include results from the recent EPA Anti-Backsliding Study (ABS), which examined the impacts of changes in vehicle and engine emissions from ethanol-blended fuels on air quality and health.[253] The ABS used fuels that are not representative of real-world fuels. The ABS used inaccurate fuel property adjustment factors in its modeling,

---

[247] Kheirbek I, Haney J, Douglas S, Ito K, Matte T, 2016. The contribution of motor vehicle emissions to ambient fine particulate matter public health impacts in New York City: a health burden assessment. Environmental Health, 15(1), pp.1-14.

[248] Pan S, Roy A, Choi Y, Eslami E, Thomas S, Jiang X, Gao HO. 2019. Potential impacts of electric vehicles on air quality and health endpoints in the Greater Houston Area in 2040. Atmospheric Environment, 207, pp.38-51.

[249] Foley TA, Rendahl CS, Kenski D. 2003. The effect of reformulated gasoline on ambient carbon monoxide concentrations in southeastern Wisconsin. Journal of the Air & Waste Management Association, 53: 1003-10.

[250] Auffhammer M, Kellogg R. 2011. Clearing the Air? The Effects of Gasoline Content Regulation on Air Quality. American Economic Review, 101 (6): 2687-2722.

[251] Sommariva R, de Gouw JA, Trainer M, Atlas E, Goldan PD, Kuster WC, Warneke C, Fehsenfeld FC. 2011. Emissions and photochemistry of oxygenated VOCs in urban plumes in the Northeastern United States. Atmospheric Chemistry & Physics, 11: 7081–96.

[252] de Gouw JA, Gilman JB, Borbon A, Warneke C, Kuster WC, Goldan PD, Holloway JS, Peischl J, Ryerson TB, Parrish DD, Gentner DR, Goldstein AH, Harley RA. 2012. Increasing atmospheric burden of ethanol in the United States. Geophysical Research Letters, 39.

[253] EPA 2020. Clean Air Act Section 211(v)(1) Anti-backsliding Study. Assessment and Standards Division Office of Transportation and Air Quality U.S. Environmental Protection Agency.

reducing aromatics by only 2%,[254] which is substantially lower than the reductions found in our paper and in fuel survey data,[255,256] as discussed earlier. As a result, ABS's findings on air quality and their extension to public health impacts are not generalizable to real world conditions.

Another chemical of concern is benzene, which has been classified as a known human carcinogen by the EPA, the National Toxicology Program, and the International Agency for Research on Cancer. This classification is based in large part on findings from animal studies which show benzene exposures cause tumors after inhalation or ingestion and from epidemiological studies which show an excess risk of leukemia in humans exposed to benzene.[257,258] Given that 40% of benzene emissions are attributed to the transportation sector and that higher ethanol fuel content has been shown to have lower emissions of BTEX (which includes benzene), greater use of higher ethanol fuel blends would further reduce benzene concentrations and their associated cancer risk.

## CORN ETHANOL FUEL BLENDS AND PUBLIC HEALTH

We identified over 20 studies that evaluated public health impacts of consumption of ethanol blends and/or E0, all of which used risk assessment approaches. We further identified seven recent epidemiological studies that examined associations between motor vehicle related exposures and cause-specific mortality, which together with results from emissions studies (detailed in the Corn Ethanol Fuel Blends and Tailpipe Emissions section), help to inform human health impact assessments.

Epidemiology studies have not focused on impacts related directly to ethanol in fuels, but instead they focus on pollutants such as PM, ozone, and benzene.[259] These studies generally show adverse human health effects associated with exposure to these pollutants, e.g., PM and ozone exposures are shown to be associated with adverse respiratory and cardiovascular outcomes. Numerous studies have also shown that lower PM emissions result in lower ambient PM concentrations and exposures, which in turn are causally associated with lower risks of total

---

[254] EPA 2020, Anti-backsliding Study. Table 5.3.
[255] Kazemiparkouhi et al. 2022a
[256] EPA. 2017. Fuel Trends Report: Gasoline 2006-2016.
[257] Filippini et al. 2019.
[258] IARC Working Group on the Evaluation of Carcinogenic Risks to Humans (IARC). 2018. Benzene. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, No. 120. 3. Cancer in Experimental Animals. Lyon (FR): International Agency for Research on Cancer.
[259] Ostro B, Hu J, Goldberg D, Reynolds P, Hertz A, Bernstein L, Kleeman MJ. 2015. Associations of mortality with long-term exposures to fine and ultrafine particles, species and sources: results from the California Teachers Study Cohort. Environmental Health Perspectives, 123: 549-56.

mortality and cardiovascular effects.[260,261,262,263] Cardiovascular disease is a leading mortality cause in the U.S., with approximately 700,000 deaths per year.[264] Using higher ethanol fuel blends therefore would reduce PM concentrations and adverse cardiovascular and respiratory outcomes.

We find considerable support from the emissions and epidemiological literature that substitution of ethanol for aromatics in automobile fuel may yield net public health benefits. In a US analysis, authors estimated that secondary fine particulate matter ($PM_{2.5}$), formed from aromatic compounds in gasoline, accounted for approximately 3,800 premature mortalities nationwide annually and $28B in total social costs.[265]

A few of the studies that we reviewed found net disbenefits for ozone, $PM_{10}$ or $PM_{2.5}$, including one study in the US [266] and two in Brazil[267,268]. However, the inputs to those analyses are either outdated (e.g., emissions data reflect outdated vehicle fleet composition), or not documented fully (e.g., missing detailed descriptions of fuel properties, which have a significant impact on emissions as discussed in earlier sections), which limits the reliability of their results. Further, these results contradict the results of the emissions analyses discussed above.

## DISCUSSION OF IMPACTS TO ENVIRONMENTAL JUSTICE COMMUNITIES

The benefits to air quality and public health associated with higher ethanol fuels may be particularly great for EJCs. EJCs are predominantly located in urban neighborhoods with high traffic density and congestion; these communities are thus exposed to disproportionately higher

---

[260] Laden F, Schwartz J, Speizer FE, Dockery DW. 2006. Reduction in fine particulate air pollution and mortality: extended follow-up of the Harvard Six Cities study. American journal of respiratory and critical care medicine, 173(6), pp.667-672.

[261] Pun VC, Kazemiparkouhi F, Manjourides J, Suh HH. 2017. Long-term PM2. 5 exposure and respiratory, cancer, and cardiovascular mortality in older US adults. American journal of epidemiology, 186(8), pp.961-969.

[262] EPA 2019. Integrated Science Assessment for Particulate Matter. Center for Public Health and Environmental Assessment.

[263] Wang B, Eum KD, Kazemiparkouhi F, Li C, Manjourides J, Pavlu V, Suh H. 2020. The impact of long-term PM2.5 exposure on specific causes of death: exposure-response curves and effect modification among 53 million U.S. Medicare beneficiaries. Environ Health, 19, 20.

[264] CDC. Heart Disease Facts. https://www.cdc.gov/heartdisease/facts.htm

[265] von Stackelberg et al. 2013.

[266] Jacobson MZ. 2007. Effects of ethanol (E85) versus gasoline vehicles on cancer and mortality in the United States. Environmental Science & Technology, 41: 4150-7.

[267] Miraglia SG. 2007. Health, environmental, and economic costs from the use of a stabilized diesel/ethanol mixture in the city of Sao Paulo, Brazil. Cad Saude Publica, 23 Suppl 4: S559-69.

[268] Scovronick N, Franca D, Alonso M, Almeida C, Longo K, Freitas S, Rudorff B, Wilkinson P. 2016. Air Quality and Health Impacts of Future Ethanol Production and Use in Sao Paulo State, Brazil. International Journal of Environmental Research and Public Health, 13.

concentrations of PM emitted from motor vehicle tailpipes.[269,270,271] For example, in New York, people of color (POC) are exposed to more $PM_{2.5}$ from light-duty gasoline vehicles and heavy-duty diesel vehicles than average (+35% and +42%).[272]

Further, vehicle trips within urban EJCs tend to be short in duration and distance, with approximately 50% of all trips in dense urban communities under three miles long.[273,274,275] As a result, a large proportion of urban vehicle operation occurs under cold-start conditions,[276] when PM emissions are highest. Given the evidence that ethanol-blended fuels substantially reduce PM during cold-start conditions,[277] it follows that ethanol-blended fuels may present an effective method to reduce air pollution-related health risks for EJCs.

Additionally, while the market-share of gasoline-powered light-duty vehicles is expected to decrease over the next 10 years due to electric vehicles (EVs), gasoline and diesel vehicles currently still account for 99% of light duty vehicles driven by the US population, as of January 2023.[278] EVs also have higher upfront costs than gasoline powered vehicles ($19,000 higher on average) [279] which may limit their market penetration until prices become more comparable.[280] Given the financial barriers to acquire an EV and the disproportionate exposure to traffic pollution for EJCs,[281] alternatives such as using higher ethanol blends may provide benefits to these communities.

[269] Bell ML, Ebisu K. 2012. Environmental inequality in exposures to airborne particulate matter components in the United States. Environmental Health Perspectives, 120, 1699-1704.
[270] Clark LP, Millet DB, Marshall JD. 2014. National patterns in environmental injustice and inequality: outdoor NO2 air pollution in the United States. PLoS One, 9, e94431.de
[271] Tian N, Xue J, Barzyk TM. 2013. Evaluating socioeconomic and racial differences in traffic-related metrics in the United States using a GIS approach. J Expo Sci Environ Epidemiol, 23, 215-22.
[272] Tessum CW, Paolella DA, Chambliss SE, Apte JS, Hill JD, Marshall JD. 2021. PM2. 5 polluters disproportionately and systemically affect people of color in the United States. Science Advances, 7(18).
[273] De Nazelle A, Morton BJ, Jerrett M, Crawford-Brown D. 2010. Short trips: An opportunity for reducing mobile-source emissions? Transportation Research Part D: Transport and Environment, 15, 451-457.
[274] Reiter MS, Kockelman KM. 2016. The problem of cold starts: A closer look at mobile source emissions levels. Transportation Research Part D: Transport and Environment, 43: 123-132.
[275] US Department of Transportation (DOT). 2010. National Transportation Statistics. Research and Innovative Technology Administration: Bureau of Transportation Statistics.
[276] de Nazelle et al. 2010.
[277] Kazemiparkouhi et al. 2022a.
[278] US DOE. 2023. The U.S. National Blueprint for Transportation Decarbonization. https://www.energy.gov/sites/default/files/2023-01/the-us-national-blueprint-for-transportation-decarbonization.pdf
[279] Hearst Autos Research. 2021. How Much Is an Electric Car?
[280] Muehlegger and Rapson 2019.
[281] Tessum et al. 2021.

## PUBLIC HEALTH BENEFITS FROM INCREASED ETHANOL FUEL CONTENT: A CASE STUDY OF NEW YORK CITY

We estimated the potential health benefits associated with the adoption of E30 gasoline blends using the motor vehicle fleet for New York City (NYC; New York, Kings, Bronx, Richmond, and Queens counties) as a case study. NYC was selected given that it would likely have higher public benefits than other US cities given its (1) high density of primary PM2.5 emissions from motor vehicles, (2) urbanicity, with large numbers of people living near roadways, and (3) high proportion of vehicle cold-starts, when PM and VOC emissions reductions for ethanol-blended fuels are greatest. We estimated public health benefits by estimating light duty vehicle (LDV) tailpipe emissions for NYC using EPA's Motor Vehicle Emission Simulator (MOVES) model and inputting estimated emissions into the CO-Benefits Risk Assessment (COBRA) tool to estimate corresponding air quality and human health benefits.

Our analysis showed that using real-world fuel properties, the PM2.5 and VOC emissions associated with E30 are lower than E10 in NYC with modest public health benefits. When LDVs moved from E10 to E30 fuels, we found a 2% reduction in motor-vehicle associated premature deaths. This small reduction in premature deaths is consistent with the fact that (1) LDVs are responsible for ~20% of all PM2.5 emitted from mobile sources,[282] which is a significant but still small portion of all motor vehicle emissions, and that (2) primary PM emissions decrease 15-18% on average with each 10% increase in ethanol content under cold-start conditions. [283]

[282] National Emission Inventory, 2014
[283] Kazemiparkouhi et al. 2022a

## CONCLUSION

We thank the Agency for this opportunity to comment on the proposed RFS Program Standards for 2023-2025 and the related 2022 DRIA.

In Part I of our letter, we began with a review of recent iLUC studies to reveal a downward trend in corn starch ethanol iLUC estimates, reflecting a 2 to 4-fold decrease from older, unrefined estimates. We discussed the basis for our LUC estimate of 3.9 gCO2e/MJ from Scully et al. 2021 and showed that recent estimates from Europe also fall within our range of -1.0 to 8.7 gCO2e/MJ. We then addressed five examples of analysis refinements, further supporting that using updated models and the best available data inputs results in a lower range of iLUC values. We also shared a recent report by IEA in which empirical statistics do not correlate US biofuel production with LUC; this conflicts with older, unrefined models that assign a large portion of ethanol's CI to LUC.

Part II focused on the topics EPA presents for comment in the Set Proposal. We appreciate EPA's literature-focused approach to developing an updated corn starch ethanol CI value. 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. If EPA does conduct a new analysis, we ask that these numbers are made available for public review and comment before they are finalized or used to inform policy.

A major component of Part II is our evaluation of the studies EPA considers in developing a well-to-wheel CI range for corn starch ethanol in the 2022 DRIA. Given that studies represent a range of scientific quality, we presented an illustrative evaluation system EPA for assessing the studies under consideration. Our example criteria assesses whether each analysis follows a generally accepted approach, utilizes refined modeling tools, uses complete data, and documents a transparent process. We also recommend that EPA's range includes several recent studies that estimate LUC only, and we evaluate those studies as well. When we look at the expanded range, the analyses that meet all four criteria have an average well-to-wheel CI of 52 gCO2e/MJ, which is in line with the 51 gCO2e/MJ central estimate from the detailed analysis in our Scully et al. 2021 study.

Within Part II, we also encouraged EPA to amortize all CI results over 30 years and consider that advancements in GHG mitigation technologies will continue to drive reductions in the CI for corn starch ethanol. We also noted that additional research is needed to understand the full CI of the petroleum gasoline baseline. We closed this section by clarifying the takeaways from a recent article about the illustrative scenario presented in the DRIA, which shows a net reduction of GHG emissions when using the proposed biofuel volumes for 2023-2025.

And for Part III, we summarized the best available science on the relationships between ethanol, tailpipe emissions, and health. As shown by papers we have published, a recent report from CARB, and numerous other studies, higher ethanol blends are associated with reductions in emissions of multiple pollutants, including BTEX and PM. As discussed, these pollutants adversely impact health and disproportionately impact EJCs. Thus, increased use of higher ethanol blends can support the RFS's GHG reduction goals and reduce the health impacts of fuels on residents, including those living in EJCs. We encourage EPA to consider these findings when generating new policies around fuel standards.

In closing, we appreciate EPA's consideration of our feedback as the Agency continues to use the best available science to refine the CI of corn starch ethanol, understand the GHG reduction benefits of corn starch ethanol, and develop related policy to maximize these benefits.

## RESOURCES

**Public Comments from EH&E**

- EH&E. 2022. Comments on the 2022 Workshop on Biofuel Greenhouse Gas Modeling. 1 April 2022. Available within: Comment Submitted by POET, LLC, pp. 9-37. https://www.regulations.gov/comment/EPA-HQ-OAR-2021-0921-0047
- EH&E. 2022. Climate Response to 2020, 2021, and 2022 Renewable Fuel Standard (RFS) Proposed Volume Standards. 3 February 2022. Available within: Comment Submitted by Growth Energy, Volume 3, pp. 110-124. https://www.regulations.gov/comment/EPA-HQ-OAR-2021-0921-0040
- EH&E. 2022. Comments on the New York State Climate Action Council Draft Scoping Plan. 1 July 2022. Available within: POET Draft Scoping Plan Comments, pp. 44-69. https://www.nyserda.ny.gov/-/media/Project/Climate/Files/2022-Comments/DSP-Comment-Cover-Letter
- EH&E. 2022. Comments on the Draft Washington Clean Fuels Program Rule (Chapter 173-424 WAC). 25 April 2022. Available within: POET Comments Re: Washington Clean Fuels Program, pp. 4-26. https://scs-public.s3-us-gov-west-1.amazonaws.com/env_production/oid100/did1008/pid_202037/assets/merged/rb01iqv_document.pdf
- EH&E. 2022. Comments on the Washington Clean Fuels Program Rule (Chapter 173-424 WAC). 31 August 2022. Available within: POET Washington State Clean Fuels Program Rule Comments, pp 15-49. https://scs-public.s3-us-gov-west-1.amazonaws.com/env_production/oid100/did1008/pid_202971/assets/merged/6f01ig9_document.pdf

**Select Papers by EH&E Authors**

- 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. https://iopscience.iop.org/article/10.1088/1748-9326/abde08/meta
- Scully, M.J., Norris, G.A., Falconi, T.M.A. and MacIntosh, D.L., 2021. Reply to Comment on 'Carbon intensity of corn ethanol in the United States: state of the science'. Environmental Research Letters, 16(11), p.118002. https://iopscience.iop.org/article/10.1088/1748-9326/ac2e36/meta

- Alarcon Falconi, T.M., Kazemiparkouhi, F., Schwartz, B. and MacIntosh, D.L., 2022. Inconsistencies in domestic land use change study. Proceedings of the National Academy of Sciences, 119(51), p.e2213961119. https://www.pnas.org/doi/abs/10.1073/pnas.2213961119
- Kazemiparkouhi, F., Falconi, T.M.A., MacIntosh, D.L. and Clark, N., 2022. Comprehensive US database and model for ethanol blend effects on regulated tailpipe emissions. Science of The Total Environment, 812, p.151426. https://www.sciencedirect.com/science/article/pii/S0048969721065049
- Kazemiparkouhi, F., Karavalakis, G., Falconi, T.M.A., MacIntosh, D.L. and Clark, N., 2022. Comprehensive US database and model for ethanol blend effects on air toxics, particle number, and black carbon tailpipe emissions. Atmospheric Environment: X, 16, p.100185. https://www.sciencedirect.com/science/article/pii/S0048969721065049


**Additional Studies We Recommend for EPA's Range**


- Carriquiry, M., Elobeid, A., Dumortier, J. and Goodrich, R., 2019. Incorporating sub-national Brazilian agricultural production and land-use into US biofuel policy evaluation. Applied Economic Perspectives and Policy, 42(3), pp.497-523. https://onlinelibrary.wiley.com/doi/abs/10.1093/aepp/ppy033
- Laborde, D., Padella, M., Edwards, R. and Marelli, L., 2014. Progress in Estimates of ILUC with MIRAGE Model. Publications Office of the European Union. https://publications.jrc.ec.europa.eu/repository/handle/JRC83815
- Valin, H., Peters, D., Van den Berg, M., Frank, S., Havlik, P., Forsell, N., Hamelinck, C., Pirker, J., Mosnier, A., Balkovic, J. and Schmidt, E., 2015. The land use change impact of biofuels consumed in the EU: Quantification of area and greenhouse gas impacts. https://pure.iiasa.ac.at/id/eprint/12310/
- Overmars, K., Edwards, R., Padella, M., Prins, A.G., Marelli, L. and Consultancy, K.O., 2015. Estimates of indirect land use change from biofuels based on historical data. JRC Science and Policy Report, Ref. no. EUR, 26819. https://publications.jrc.ec.europa.eu/repository/handle/JRC91339

**Criticisms of Lark et al. 2022 Study**


- Taheripour, F., Mueller, S., Kwon, H., Khanna, M., Emery, I., Copenhaver, K., Wang, M. and CropGrower, L.L.C., Comments on "Environmental Outcomes of the US Renewable Fuel Standard". https://greet.es.anl.gov/files/comment_environ_outcomes_us_rfs
- Taheripour, F., Mueller, S., Kwon, H., Khanna, M., Emery, I., Copenhaver, K., Wang, M. and CropGrower, L.L.C., 2022. Response to comments from Lark et al. regarding Taheripour et al. March 2022 comments on Lark et. al. original PNAS paper. https://greet.es.anl.gov/files/comment_environ_outcomes_us_rfs2
- USDA. 2022. Technical Memorandum: Review of Recent PNAS Publication on GHG Impacts of Corn Ethanol. https://www.usda.gov/sites/default/files/documents/USDA-OCE-Review-of-Lark-2022-For-Submission.pdf