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4/25/2022

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*Submitted online via: Rulemaking - Informal Public Comment Period for Chapter 173-424 WAC, Clean Fuels Program Rule (commentinput.com)*

**RE: Washington Clean Fuels Program Rule**

Dear Mr. Creswell:

POET is pleased to submit these comments to the Washington Department of Ecology in support of the agency's Clean Fuels Program rulemaking and in response to Ecology's meeting on April 13th, 2022.[1] POET supports the Washington Clean Fuel Standard's goal of reducing greenhouse gas ("GHG") emissions from the Washington transportation sector. Increasing renewable alternatives aligns with POET's mission and is essential to mitigating climate change and protecting human health and the environment.

This letter supplements the comments that POET previously submitted during this rulemaking process on March 25, 2022. In that letter, we recommended several actions that Ecology can take to more appropriately measure and account for the carbon intensity ("CI") of ethanol production. In addition to providing the comments below, we again encourage Ecology to review and implement our prior recommendations.

## About POET

POET's vision is to create a world in sync with nature. As the world's largest producer of biofuels and a global leader in sustainable bioproducts, POET creates plant-based alternatives to fossil fuels that utilize the power of agriculture and cultivate opportunities for America's farm families. Founded in 1987 and headquartered in Sioux Falls, POET operates 33 bioprocessing facilities across eight states and employs more than 2,200 team members. With a suite of bioproducts including Dakota Gold and NexPro feed, Voilà corn oil, purified alcohol, renewable $CO_2$ and JIVE asphalt rejuvenator, POET is committed to innovation and advancing solutions to some of the world's most pressing challenges. POET holds more than 80 patents and continues to break new ground in biotechnology, yielding ever-cleaner and more efficient renewable energy. In 2021, POET released its inaugural Sustainability Report pledging carbon neutrality by 2050.

## Background

On March 15, 2022, Ecology held a stakeholder meeting during which the agency presented a draft WA-GREET model. As part of this draft model, the agency presented a proposed indirect land use change ("iLUC") calculation prepared by Life Cycle Associates.[2] POET submitted a comment letter in support of this iLUC calculation on March 25, 2022, explaining that most scientific assessments support a lower iLUC

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[1] RCWA, Transportation Fuel—Clean Fuels Program, § 70A.535 (2021).
[2] Unnasch, Stefan, *Indirect Land Use Conversion for Washington Clean Fuels Standard*, LIFE CYCLE ASSOCIATES, 5 (2022) https://ecology.wa.gov/Asset-Collections/Doc-Assets/Rulemaking/AQ/WAC173-424_455_-21-04/Indirect-Land-Use-Conversion-WAC-173-424-03-08-22.

calculation than presented by CA GREET3.0 and encouraging Ecology to continue to incorporate the best-available science in its iLUC assessments.

Ecology commissioned a peer review of the draft WA-GREET model by ICCT, and on April 13, 2022, held a stakeholder meeting during which ICCT presented its review of the draft WA-GREET. As part of its peer review, ICCT critiques Life Cycle Associates' selection of the iLUC value for corn ethanol adopted under the Oregon Clean Fuels Program and based on modeling by Argonne National Laboratory.[3] POET disagrees with ICCT and supports Ecology's adoption of the iLUC value Life Cycle Associates recommends. Below we briefly explain our disagreements, and we attach as Attachment A an analysis of the ICCT peer review from Environmental Health and Engineering, Inc. ("EH&E"). We also briefly discuss significant non-greenhouse gas emissions benefits of higher ethanol blends and commend Ecology for allowing for offsite renewable energy to reduce the carbon intensity of biofuels in the portion of the draft regulations that have been released.

## POET's Comments

### I. iLUC

POET supports Ecology's adoption of a 7.6 iLUC value for corn bioethanol as described in the Life Cycle Associates report.[4] As highlighted in our prior comments and the attached EH&E report, the Life Cycle Associates value is much more consistent with recent science on iLUC.

Further, and as discussed by EH&E, we note that ICCT's peer review omits much of the recent literature on iLUC. ICCT presents its critiques of the Life Cycle Associates report as novel, but does not cite to existing literature that has already presented similar arguments, nor additional literature that thoroughly rebuts those arguments. When evaluating the merits of the ICCT peer review, POET strongly recommends to Ecology that it carefully consider the iLUC literature omitted from the review. We believe that such careful consideration will explain why most recent iLUC models are converging on similar numbers that are consistent with the Life Cycle Associates report.

### II. Ethanol's Emissions and Health Benefits

Aside from addressing the ICCT report, the attached EH&E analysis highlights significant non-greenhouse gas benefits associated with higher ethanol blends. Peer-reviewed papers and recent real-emissions testing conducted by the University of California Riverside indicate that higher ethanol blends are associated with reductions in a number of pollutants, including particulate matter, carbon monoxide, volatile organic compounds, and potentially nitrogen oxides. These additional emissions benefits amplify the role that higher ethanol blends could play in improving the environment in Washington State.

### III. Low-CI Process Energy

In our last comments, POET encouraged Ecology to depart from California's approach and allow offsite renewable energy sources to reduce the carbon intensity of biofuels in the Washington Clean Fuels Program. POET was pleased that during the public meeting on March 15, 2022, Ecology stated that the

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[3] *Washington Clean Fuels Standard—Carbon Intensity Model Peer Review*, THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION, 21 (2022), https://ecology.wa.gov/DOE/files/3f/3ff97fb5-9ba4-4507-8741-4be625e4e690.pdf.

[4] Unnasch, Stefan, *Indirect Land Use Conversion for Washington Clean Fuels Standard*, LIFE CYCLE ASSOCIATES, 5 (2022) https://ecology.wa.gov/Asset-Collections/Doc-Assets/Rulemaking/AQ/WAC173-424_455_-21-04/Indirect-Land-Use-Conversion-WAC-173-424-03-08-22.

agency intended to allow for book-and-claim accounting for off-site renewable energy production for usage at biofuel production facilities.

Additionally, POET is pleased that the initial draft regulatory language for the Clean Fuels Program appears to contemplate off-site renewable electricity contributing to lower carbon intensity. Specifically, draft WAC-173-424-OIC subsection (9)(g)(iii)(C) discusses the retirement of environmental attributes in fuel production processes involving renewable electricity. Subsection (9)(g)(iii)(D) then allows the use of third-party verifiers or invoices to demonstrate the use of renewable or low-CI process energy. Further, that subsection seems to distinguish between requirements for certain types of directly connected renewable electricity and other renewable energy sources. POET encourages Ecology to further clarify and elaborate on the acceptability of off-site renewable electricity to reduce the carbon intensity of biofuels in its final rulemaking package.

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POET strongly supports the Washington Clean Fuels Program. We appreciate Ecology's consideration of these comments and look forward to engaging in a productive dialogue with the Agency on the Clean Fuels Program and the role biofuels play in helping Washington achieve its GHG reduction goals. If you have any questions, please contact me at Matt.Haynie@POET.COM or (202) 756-5604.

Sincerely,

Matthew Haynie
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**Attachment A**

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April 25, 2022

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Comments of David MacIntosh[1,2], Tania Alarcon[1,3], Fatemeh Kazemiparkouhi[1], Brittany Schwartz[1]
[1] Environmental Health & Engineering, Inc., Newton MA
[2] Harvard T.H. Chan School of Public Health, Boston, MA
[3] Tufts University, Boston, MA

**RE: Comments on the draft Washington Clean Fuels Program Rule (Chapter 173-424 WAC)**

We are writing to provide comments on the indirect land use change (iLUC) emission rates recommended to Washington Department of Ecology (WDE) by its contractor, Life Cycle Associates, Inc. (LCAInc), and its peer reviewer, International Council on Clean Transportation (ICCT), for the draft Washington Clean Fuels Program Rule (Chapter 173-424 WAC). Following those comments, we provide additional information on our recent published research on tailpipe emissions of regulated pollutants and air toxics from the combustion of ethanol fuel blends in light-duty vehicles.

We at Environmental Health & Engineering, Inc. (EH&E) are a multi-disciplinary team of environmental health scientists and engineers with expertise in measurements, models, data science, LCA, and public health. Members of our team conducted a state of the science review of the carbon intensity (CI) for corn ethanol in the United States (U.S.)[1] and a comprehensive assessment of the impacts of corn ethanol fuel blends on tailpipe emissions.[2,3] Our experience informs the comments that follow.

Our comments compare the proposed Washington (WA) iLUC emissions with the best available science, review the ICCT report that critiques the proposed WA iLUC, and demonstrate why

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[1] 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.

[2] Kazemiparkouhi F, Alarcon Falconi TM, Macintosh DL and Clark N. 2022a. Comprehensive US database and model for ethanol blend effects on regulated tailpipe emissions. *Sci Total Environ*, 812, 151426.

[3] Kazemiparkouhi F, Karavalakis G, Alarcon Falconi TM, Macintosh DL 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* [under review].

adoption of the proposed WA iLUC value is appropriate. We also discuss the relationship between ethanol, tailpipe emissions, and health. Our detailed comments on those topics are presented following the summary.

## SUMMARY

In reviewing the information presented by LCAInc, we find that their suggestion to incorporate an iLUC value of 7.6 gCO2e per MJ ethanol is in line with current research. ICCT, in their peer review, recommends that WDE consider a value generated by the California Air Resources Board (CARB) in 2015 instead. Yet, when looking at iLUC estimates generated by researchers in both US and Europe, the value from CARB falls outside the range of other results, as does the 2010 estimate from the U.S. Environmental Protection Agency (USEPA). The value proposed by LCAInc, however, lines up nearly in the middle of these recent results.

We examined the ICCT comments in detail and found their review to be incomplete. Still, in this letter we address each of ICCT's criticisms toward LCAInc's iLUC recommendations. First, ICCT critiques the choice of model, yet the selected model is widely accepted, regularly updated, and relied up on by Argonne National Laboratory, among others. Second, ICCT calls out limitations of the emissions factors used, even though the estimates are in line with techniques used by the Intergovernmental Panel on Climate Change and are based on evidence from U.S. Department of Agriculture (USDA) statistics. The ICCT report states that the model used does not make unmanaged forest available to be used as cropland; however, some unmanaged forests are in fact included in the accessible forest areas that the model considers and would have a small impact on iLUC anyway. Next, ICCT describes the chosen estimated price-induced corn yield (YDEL) as outside of a justifiable range, but we find that a review of recent studies places the selected YDEL value right inside the acceptable span. The ICCT report also takes issue with the inclusion of double cropping; we explain that the model includes a land intensification factor to properly determine harvest frequency based on regional factors and land use change observed over the period of rapid expansion of U.S. ethanol production. Finally, ICCT provides criticism on the classification of cropland pasture, which may have been an accurate comment for previous model versions but has been resolved with better functionality of recent versions of the selected model.

We close our letter by recognizing that the present yet manageable uncertainty around iLUC estimates must not hinder policy decisions, which should rely on the best available science. To support this, we give examples of policies implemented by public health organizations in the presence of uncertainty. We then explain how gasoline-powered light-duty vehicles will still be used by most individuals in the U.S. over the next 10 years. While electric vehicle (EV) sales are anticipated to increase, many individuals will find financial barriers to their uptake and continue to rely on gasoline-powered vehicles. We expect that shifting some of this gasoline use to higher ethanol blends will benefit the communities which are disproportionally impacted by exposure to traffic pollution and, thus, policy supporting this shift should not be delayed.

## ILUC CARBON EMISSION RATES

### Background

Life Cycle Associates, under contract with WDE, assessed multiple iLUC estimates for corn starch ethanol and recommended WDE adopt the iLUC estimate of 7.6 gCO2e per MJ ethanol used in the Oregon Clean Fuels Program.[4,5] As explained below, this carbon emission rate is consistent with current iLUC estimates observed across numerous frequently relied upon analyses.

iLUC and associated carbon emissions associated with use of corn starch ethanol in light-duty vehicles has been a subject of active research since at least 1990. iLUC emissions result from a market-mediated (economic) dynamics and land (e.g., biomass) characteristics that manifest at different rates and to different degrees at different locations. Hence, iLUC emissions cannot be observed or measured directly. iLUC emissions are therefore simulated using: (1) a class of mathematical models often termed agroeconomic models to estimate indirect land use change in response to demand for a biofuel combined with (2) databases of emission factors (EF) that describe the amount of carbon dioxide equivalent emissions per area of land converted from its current use to a new use.

The agroeconomic models relied upon most commonly by government authorities for estimates of iLUC in response to biofuel demand are Global Trade Analysis Project-biofuel model (GTAP-BIO-ADV), Food and Agricultural Policy Research Institute-Center for Agricultural and Rural Development (FAPRI-CARD), MIRAGE, and Global Biosphere Management Model (GLOBIOM), with the first two used primarily in the United States and the latter two used primarily in the European Union. The EF databases relied upon most commonly are CENTURY, Winrock, and AEZ. Extensive documentation of these models and databases is available in the peer-reviewed literature and reports. Here, we address aspects of the models and databases that are most relevant to the recommendation from LCAInc and peer review of ICCT.

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[4] Unnasch S. 2022. Indirect Land Use Conversion for Washington Clean Fuels Standard. [Presentation] https://ecology.wa.gov/DOE/files/26/26c03a09-487d-4b7f-a568-d88c5981423a.pdf

[5] State of Oregon Department of Environmental Quality. 2020. Notice of Proposed Rulemaking: Clean Fuels Program Electricity 2021 Rulemaking. https://www.oregon.gov/deq/Regulations/rulemaking/RuleDocuments/CFPE2021Notice.pdf

## Best Available Science on ILUC

We assessed the best available science on iLUC emissions associated with corn starch ethanol as applied to biofuel policy in the U.S. and published our findings in a peer-reviewed journal in January 2021.[6] Since then, we have expanded our assessment to include the most recent U.S.-based estimates and iLUC results from modeling tools used in the European Union (EU) and adopted by the European Commission (EC).

The plot in Figure 1 presents iLUC estimates for the ~12 billion gallon increase in U.S. demand for corn starch ethanol from 2004 – 2010 that meet our criteria for best available science[7] in comparison to prior and now superseded estimates from the U.S. Environmental Protection Agency (USEPA) in 2010 and California Air Resources Board (CARB) in 2015. [8,9,10,11,12] The current estimates of iLUC GHG impacts are 2-fold to 4-fold lower than the earlier estimates from USEPA and CARB. iLUC emission estimates from the most current modeling efforts and policy in the U.S. (blue dots) are in good agreement with those from Europe (red dots).

Of note for WDE, the iLUC emission rate adopted by Oregon and proposed for Washington falls at the approximate mid-point of the values from the best available science.

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[6] Scully et al. 2021a.

[7] Our criteria include use of (1) the latest available measurable and observable inputs such as energy consumption and fertilizer use during feedstock and ethanol production and (2) generally accepted, frequently used, fully documented, and calibrated or tuned methods for estimation of direct and indirect land use change.

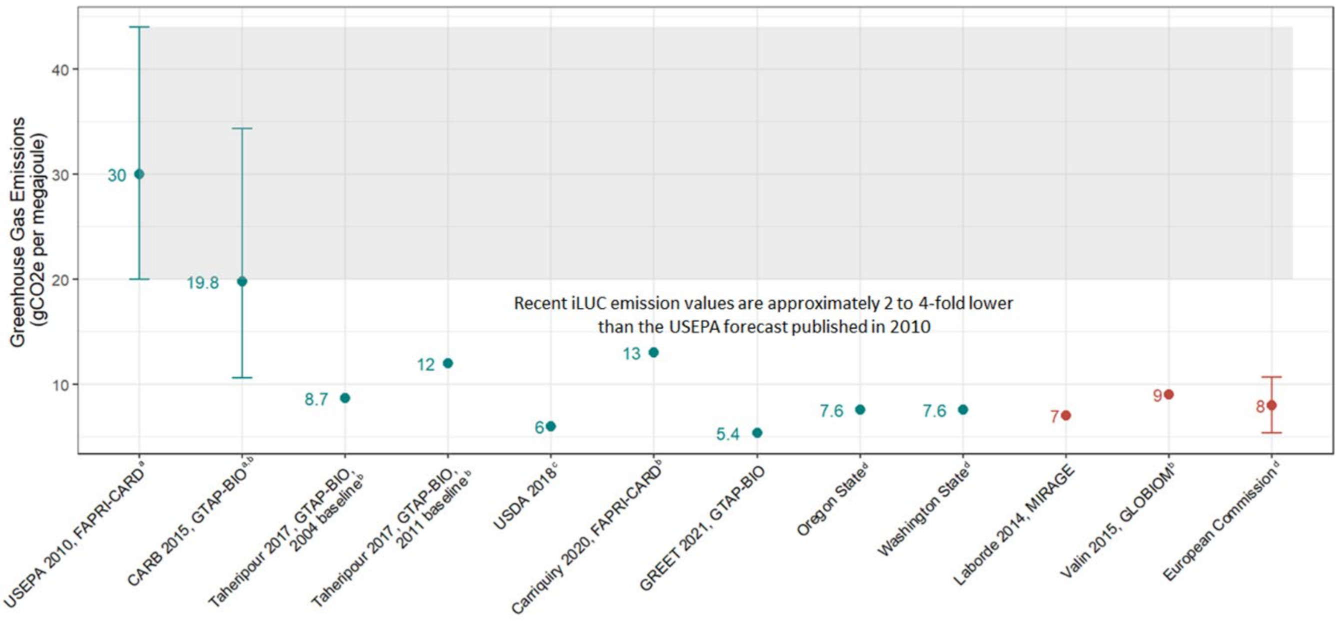
[8] Lee U, Hoyoung K, Wu M, Wang M. 2021. Retrospective analysis of the U.S. corn ethanol industry for 2005-2019: implications for greenhouse gas emission reductions. *Biofuels, Bioproducts & Biorefining*, 15(5), pp.1318-1331.

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

[10] Taheripour F, Mueller S, 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.

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

[12] Scully et al. 2021a.



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

**Figure 1** Comparison of Washington State's proposed iLUC with relevant most recent studies and values used in the regulatory context in the U.S. and Europe

Like many models that are relevant to scientific discovery or policy, the tools used to characterize iLUC emissions have been further developed and refined over time with the goal of providing more accurate and reliable estimates. The observed changes in estimates of iLUC impacts over time are attributable primarily to: (1) addition of new modules that allow for more accurate simulation of real-world agricultural practices, (2) addition of more spatially resolved information on land cover, and (3) tuning of parameters that describe rates of land conversion and land transformation.[13],[14],[15],[16],[17],[18] Our publication on LCA of corn ethanol[19] and our reply to comments on the paper,[20] as well as a recent retrospective analysis of corn ethanol LCAs by

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

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

[15] Carriquiry et al. 2020.

[16] 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.

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

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

[19] Scully et al. 2021a.

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

Lee et al.,[21] summarize the enhancements made to FAPRI and GTAP-BIO, two iLUC models used in U.S. regulatory contexts for evaluation of corn ethanol.

In its peer review for WDE, ICCT critiqued the iLUC value of 7.6 gCO2e/MJ proposed to WBE by LCAInc and recommended WDE adopt the 2015 CARB iLUC value of 19.8 gCO2e/MJ instead. Its opinion appears to largely rely on criticisms of recent advances in the agroeconomic models and EF databases. As described in the next section, we disagree with the ICCT conclusion and note the CARB 2016 analysis that it recommends used an outdated version of GTAP-BIO which no longer represents the best available science.

## ICCT Review

ICCT raised six main concerns in their critique of LCAInc's iLUC approach: (1) choice of agroeconomic model; (2) choice of land conversion EF database; (3) conversion of unmanaged forests; (4) price-induced corn yield (YDEL); (5) double cropping; and (6) classification of cropland pasture. We provide comments on each area of concern in the sections below. However, we first comment on the completeness of the review provided in the ICCT report.

### *Completeness of the ICCT peer review*

Information on the strengths and weaknesses of GTAP-BIO-ADV presented in the ICCT peer review report is incomplete for it only presents perspectives held by critics of the model. The six areas of concern identified by ICCT (see preceding paragraph) were raised in two prior publications; one is an original paper, and the other is a published commentary on an original paper.[22,23] The ICCT report simply repeats criticisms that appear in those two publications. However, the report does not incorporate perspectives of the model developers including the rationale for the updates and discussion of their strengths and weaknesses.[24] The report also does not present perspectives of analysts and researchers who use the model and that have been published in the peer-reviewed scientific literature,[25,26] including publications prepared specifically in response to criticisms levied against the model and the modeling results.[27,28] For

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[21] Lee et al. 2021.

[22] Malins C, Plevin R, Edwards R. 2020. How robust are reductions in modeled estimates from GTAP-BIO of the indirect land use change induced by conventional biofuels?. *Journal of Cleaner Production*, 258, p.120716.

[23] Spawn-Lee SA, Lark TJ, Gibbs HK, Houghton RA, Kucharik CJ, Malins C, et al. 2021. Comment on 'Carbon intensity of corn ethanol in the United States: state of the science'. *Environmental Research Letters*, 16(11), pp.118001.

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

[25] Lee et al. 2021.

[26] Scully et al. 2021a.

[27] Scully et al. 2021b.

[28] Taheripour F, Mueller S, 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.

these reasons, we find that the ICCT peer review of the iLUC emission rate proposed by Washington, and adopted by Oregon, is incomplete.

### *Selection of agroeconomic model*

ICCT provides a critique of GTAP-BIO-ADV (hereafter "GTAP"), the agroeconomic model used to calculate WA's proposed iLUC, noting that inputs may not reflect real-world conditions and that its underlying datasets are incomprehensive.[29] GTAP is a computable general equilibrium (CGE) model that addresses land intensification and expansion on regional and national scales globally. The model predicts LUC for specific land types based on both economic and physical data. In 2010, USEPA stated that "since its inception in 1993, GTAP has rapidly become a common 'language' for many of those conducting global economic analysis."[30] GTAP is used by major corn ethanol life cycle analysis (LCA) modeling groups such as Argonne National Laboratory (ANL), CARB, and USEPA. Moreover, the model is generally accepted as evidenced by the numerous peer-reviewed publications that use it in evaluations of the global implications of biofuel production and policy and other environmental and trade topics.[31, 32, 33, 34, 35, 36, 37]

A distinguishing advantage of GTAP is its ability to account for linkages of the biofuel industry with other economic activities on a global scale.[38]

In addition to being widely used and generally accepted, GTAP is regularly updated to generate more refined and accurate estimates of LUC, including those associated with biofuels.[39, 40] Briefly, since 2010 GTAP has been updated to include: market mediated factors; co-products of biofuel refining such as animal feed (distillers' dried grains with solubles), regional extensive margins by agroeconomic zone (AEZ); 2004, 2007, and 2011 economic databases; land

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[29] ICCT. 2022. Washington Clean Fuels Standard – Carbon Intensity Model Peer Review. https://ecology.wa.gov/DOE/files/3f/3ff97fb5-9ba4-4507-8741-4be625e4e690.pdf

[30] USEPA. 2005. Renewable fuel standard (RFS1): final rule.

[31] Lee U et al. 2021.

[32] Taheripour et al. 2017.

[33] Hertel TW, Golub AA, Jones AD, O'Hare M, Plevin RJ, Kammen DM. 2010. Effects of US maize ethanol on global land use and greenhouse gas emissions: estimating market-mediated responses. *BioScience*, 60(3), pp.223-231.

[34] Tyner W, Taheripour F, Zhuang Q, Birur D, Baldos UL. 2010. Land use changes and consequent CO2 emissions due to US corn ethanol production: A comprehensive analysis.

[35] Taheripour and Tyner 2013.

[36] Dunn et al. 2013.

[37] Wang M, Han J, Dunn JB, Cai H, Elgowainy A. 2012. Well-to-wheels energy use and greenhouse gas emissions of ethanol from corn, sugarcane and cellulosic biomass for US use. *Environmental research letters*, 7(4), p.045905.

[38] Kretschmer B and Peterson S. 2010. Integrating bioenergy into computable general equilibrium models—A survey. *Energy Economics*, 32(3), pp.673-686.

[39] Taheripour et al.2017.

[40] Taheripour et al. 2021b.

transformation elasticities on a regional scale; region-specific multiple cropping; and land cover nesting structure that includes idled cropland.[41]

### *Limitations of CCLUB*

ICCT criticizes the choice of CCLUB as the emissions factor model primarily because CCLUB uses CENTURY and Winrock EF as the default for characterizing carbon in biomass and soil organic carbon (SOC) rather than Agro-ecological Zone Emission Factors (AEZ-EF).[42] An advantage of the CENTURY EF is their potential to account for a broad range of soil characteristics, climate, and management conditions. [43] The CENTURY approach to EF "is consistent with the technique of the Intergovernmental Panel on Climate Change of continuously updating carbon stock change factors based on such factors as management activities and various yield scenarios."[44]

The ICCT report also challenges how the CENTURY EF in CCLUB treat emissions associated with transitioning cropland pasture to cropland and recommend using instead the AEZ-EF.[45] The AEZ-EF simply assume converting cropland pasture to cropland releases 50% of the emissions associated with converting pasture to cropland.[46] However, emissions associated with conversion of cropland pasture to cropland are likely to be lower due to periodic tilling since cropland pasture typically "shifts back and forth between cropland and grassland depending on the net returns". [47] The treatment of cropland pasture in CENTURY appears to be more evidence-based than the method utilized by AEZ-EF, since it is informed by USDA statistics.[48]

### *Conversion of unmanaged forests*

ICCT calls out that, in GTAP, unmanaged forests are treated as unavailable for conversion to cropland.[49] However, this criticism has no material bearing on iLUC estimates as GTAP accounts for accessible forest area, which includes managed forests and some unmanaged forests, where accessibility is a function of distance to infrastructure.[50] The absence of an

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[41] Ibid.

[42] ICCT 2022.

[43] Taheripour et al. 2021b.

[44] Ibid.

[45] ICCT 2022.

[46] Plevin RJ, Gibbs HK, Duffy J, Yui S, Yeh S. 2014. Agro-ecological zone emission factor (AEZ-EF) model (v47) (No. 1236-2019-175).

[47] Claassen R, Carriazo F, Cooper J C, Hellerstein D, Ueda J. 2011 Grassland to cropland conversion in the northern plains: the role of crop insurance, commodity, and disaster programs. ERR-120. U.S. Dept. of Agri., Econ. Res. Serv. 1–77.

[48] Taheripour et al. 2021b.

[49] ICCT 2022.

[50] Hertel, T., Golub, A., Jones, A., O'Hare, M., Plevin, R. and Kammen, D., 2009. Global land use and greenhouse gas emissions impacts of US Maize ethanol: the role of market-mediated responses.

explicit compartment for unmanaged forest has no effect on EF because emissions factors that distinguish between managed and unmanaged forest have yet to be developed.[51, 52]

### *Price-induced yield*

ICCT critique the use of a YDEL factor of 0.25 because it is “greater than the high-end range estimated by expert reviewers, and is only justified on the basis that it implicitly includes the yield effects of double cropping.”[53] These concerns have been raised and addressed in previous publications.[54, 55, 56, 57] We briefly discuss YDEL here and address the potential for double cropping in the next section.

In our state of the science review of the CI for corn ethanol in the U.S., we conducted a literature review to identify raw YDEL values, calculated the average of those values (0.23), and compared that average to the commonly used YDEL of 0.25.[58] A YDEL of 0.25 appears to be commonly used as our analysis showed that 17 of the 27 LUC estimates we considered were derived using a YDEL of 0.25 (see Supplemental materials for Scully et al. 2021a). Separately, the CARB expert work group on YDEL also recommended a YDEL of 0.25.[59] The CARB expert group also opined on when a range of YDEL values, in consideration of multiple cropping, may be appropriate: “If differentiation [in YDEL] can occur by country, then setting the price elasticity to 0.175 for countries with no double cropping, 0.25 for the U.S. and 0.3 for Brazil and Argentina [with higher rate of double cropping] will provide a more reasonable approximation to reality”.[60, 61]. Subsequently, Taheripour et al. expanded upon the CARB expert work group’s recommendation by analyzing global, region-specific land use data to develop “a full set of regional YDEL values based on the observed regional yields obtained from the FAO data set from 2003-2013”.[62] Based on these considerations, we concluded that the current most credible YDEL range is 0.175-0.325, since it was supported by CARB’s expert group, is inclusive of the commonly used value of 0.25, and is corroborated by the average YDEL calculated from 20 relevant studies on corn YDEL dating from 1976-2017. Our review of the state of the science thus shows that a YDEL of 0.25 is appropriate and lower than the high end of the current most credible range.

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[51] Plevin et al.2014.
[52] Kwon et al.2020.
[53] ICCT 2022.
[54] Malins et al.2020.
[55] Spawn-Lee et al.2021.
[56] Scully et al. 2021b.
[57] Taheripour et al. 2021b.
[58] Scully et al. 2021a.
[59] Babcock B, Gurgel A, Stowers M. Final Recommendations From Elasticity Values Subgroup. ARB LCFS Expert Workgroup; 2011.
[60] Taheripour et al.2021a.
[61] Babcock et al.2011.
[62] Taheripour et al.2021a.

### *Double cropping*

According to ICCT, a YDEL of 0.25 "can only be justified if double cropping is not explicitly included in the modeling to minimize the risk of underestimating ILUC emissions."[63] Their critique is focused on the LUC values that were calculated by Taheripour et al. (2017) which applied regional land intensification parameters in addition to regional YDELs.[64] This concern was raised and addressed in previous publications, and we encourage WDE to review those papers for details on this topic.[65,66,67] Briefly, GTAP was updated with a land intensification parameter to "represent improvement in harvest frequency due to multiple cropping and/or conversion of idled cropland to crop production".[68] The land intensification parameter is empirically-based and parameterized using regional "FAO data based on actual observations on regional harvested area and cropland area".[69,70] The region-specific land intensification parameter in addition to region-specific YDELs allows GTAP to account for observed corn yield response, harvest frequency, and conversion of idled cropland to crop production, informed by empirical data.[71] Inclusion of the land intensification parameter improved agreement between model estimates and empirical information for cropland extensification on a regional scale across the globe.[72]

### *Classification of cropland pasture*

The ICCT report challenges how GTAP treats cropland pasture conversion, primarily because of recent model updates that include adjusted land transformation elasticities.[73] Land transformation elasticities "reflects the ease of land transition from one state to another".[74] Updates to GTAP included using two "United Nations FAO land cover data sets [from 1990-2010] to develop region-specific land transformation elasticities", rather than using a single land transformation elasticity value for the globe.[75,76] Additionally, older versions of GTAP assumed the costs for converting pasture and forest to cropland were identical, while "often the opportunity costs of converting forest to cropland is higher than the economic costs of converting

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[63] ICCT 2022.
[64] Taheripour et al.2017.
[65] Ibid.
[66] Malins et al.2020.
[67] Taheripour et al.2021a.
[68] Taheripour et al. 2021b.
[69] Taheripour et al.2017.
[70] Taheripour et al. 2021b.
[71] Taheripour et al.2017.
[72] Taheripour et al. 2021b.
[73] ICCT 2022.
[74] Kwon et al.2020.
[75] Taheripour and Tyner 2013.
[76] Kwon et al.2020.

pastureland to cropland".[77] Taheripour and Tyner updated GTAP to categorize regions as having a low, medium, or high land transformation elasticity and reflect the greater cost of converting forest to cropland than converting pastures based on empirical data and real world observations.[78],[79] These model updates resulted in GTAP "producing results more consistent with historical observations".[80]

## UNCERTAINTY IN ILUC

ICCT's peer review notes that "ILUC emissions remain uncertain due to data limitations as well as disagreements on model choice, scenario design, and risk tolerance." While we agree that uncertainty exists, we note that the distribution of uncertainty around central estimates of iLUC is reasonably well characterized in the literature. The level of uncertainty present around iLUC does not warrant that government agencies disregard updated data and models when making policy decisions.

USEPA and others have used Monte Carlo and similar simulation methods to characterize the effects of parameter uncertainty on estimated iLUC impacts.[81],[82] These analyses report distributions of uncertainty about iLUC estimates for corn ethanol that are approximately symmetric or moderately right-skewed with a coefficient of variation of approximately 20%. Although the formal uncertainty analyses were performed as part of older studies, we are not aware of a reason why uncertainty about present iLUC emission estimates would be greater than the prior estimates. This amount of uncertainty is comparable to uncertainty in other environmental public health analyses. For example, the accepted irreducible error in standard environmental measurements is typically approximately 15%. Another example relates to exposure to chemical hazards: the dose-response relationships for chemicals hold relatively high uncertainty, typically in the range of 100-fold (10,000%) to 1,000-fold (100,000%).[83],[84],[85] In both of these cases, regulatory agencies, such as USEPA, are able to accept the uncertainty and use estimates to implement policy and provide guidance to the public.

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[77] Taheripour and Tyner 2013.

[78] Taheripour and Tyner 2013.

[79] Kwon et al.2020.

[80] Taheripour et al.2021a.

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

[82] Laborde et al. 2014.

[83] USEPA. Reference Dose (RfD): Description and Use in Health Risk Assessments. Background Document 1A. https://www.epa.gov/iris/reference-dose-rfd-description-and-use-health-risk-assessments#1.3.2

[84] USEPA. 2021. External Peer Review Draft, Proposed Approaches to the Derivation of a Draft Maximum Contaminant Level Goal for Perfluorooctanoic Acid (PFOA) in Drinking Water, U.S Environmental Protection Agency, ed. Washington, DC.

[85] USEPA. 2021a. External Peer Review Draft, Proposed Approaches to the Derivation of a Draft Maximum Contaminant Level Goal for perfluorooctane sulfonic acid (PFOS) in Drinking Water, D. Washington, ed.

While uncertainty may always be present when calculating iLUC emissions, there are signs of uncertainty reduction given the converging iLUC estimates, as we discussed in our section on the Best Available Science on iLUC above. Current central estimates of iLUC impacts are of similar magnitude despite being the product of models with different methods, designs, data, and parameter values. We showed above that the proposed WA iLUC emission estimate is in good agreement with the most current modeling efforts and policy in the U.S. and in Europe (Figure 1). In contrast, the estimated iLUC values from CARB 2015 are based on an outdated version of GTAP-BIO that has been superseded and no longer represents the best available science. When considering uncertainty in iLUC, we recommend WDE review studies that represent best available science and not rely on those that use outdated models.

## IMPLICATIONS OF HIGHER ETHANOL FUEL BLENDS

To emphasize why agencies must use the best available science and not allow uncertainty to hinder policy decisions, we provide a brief summary of how using higher ethanol blends for gasoline-powered vehicles is an important pathway to reduce the CI of the transportation sector. While the market-share of gasoline-powered light-duty vehicles is expected to decrease over the next 10 years, they still account for a majority of the vehicles driven by the U.S. population. Sales of electric vehicles (EV) in the U.S. accounted for only 1.7% of new car sales in 2020 [86] and are estimated to reach 30% by 2030.[87] Additionally, EVs have higher upfront costs than gasoline powered vehicles ($19,000 higher on average) [88] which may limit their market penetration until prices become more comparable.[89] Given the financial barriers to acquire an EV and the disproportionate exposure to traffic pollution for the environmental justice (EJ) communities,[90] alternatives such as using higher ethanol blends may provide significant benefits to these communities.

Most gasoline used for light duty vehicles in the U.S. is E10, which contains a blend of 10% (by volume) ethanol with a gasoline blendstock. We recently evaluated the impacts of ethanol fuel blending on tailpipe emissions,[91,92] and summarized the results and discussed implications for

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[86] Oak Ridge National Laboratory. 2021. https://tedb.ornl.gov/wp-content/uploads/2021/05/Table6_02_04302021.xlsx (accessed 22 April 2022).

[87] EVAdoption. https://evadoption.com/ev-sales/ev-sales-forecasts/ (accessed 22 April 2022).

[88] Hearst Autos Research. https://www.caranddriver.com/research/a31544842/how-much-is-an-electric-car/. (accessed 22 April 2022)

[89] Muehlegger E and Rapson D. 2019. Understanding the Distributional Impacts of Vehicle Policy: Who Buys New and Used Electric Vehicles? UC Davis: National Center for Sustainable Transportation. http://dx.doi.org/10.7922/G21Z42N Retrieved from https://escholarship.org/uc/item/1q259456

[90] Tessum CW, Paolella DA, Chambliss SE, Apte JS, Hill JD and Marshall JD. 2021. PM2.5 polluters disproportionately and systemically affect people of color in the United States. Science advances, 7(18).

[91] Kazemiparkouhi et al. 2021a.

[92] Kazemiparkouhi et al. 2021b.

air quality and public health in a white paper (Attachment A).[93] We provide a short summary of that work in this letter. We found that tailpipe emissions of particulate matter (PM) decreased with increasing ethanol content under cold-start conditions.[94] Emissions of carbon monoxide (CO) and total hydrocarbons (THC) also generally decreased with increasing ethanol fuel content under cold running conditions, while oxides of nitrogen (NOx) emissions did not change.[95] Air toxic emissions showed lower BTEX, 1-3 butadiene, black carbon, and particle number emissions with increasing ethanol content in summer market fuels.[96] Notably, our findings are consistent with a recent CARB study that assessed the impact of splash-blending E10 to E15 on PM and other air pollutant emissions for late model year vehicles (2016-2021).[97,98]

The estimated reductions in air pollutant emissions, particularly of PM, indicate that increasing ethanol content offers opportunities to improve air quality and public health. Numerous studies have shown that lower PM emissions result in lower ambient PM concentrations and exposures,[99,100] which, in turn, are causally associated with lower risks of total mortality and cardiovascular effects.[101,102,103,104] Our findings demonstrate the potential for policies that encourage higher concentrations of ethanol in gasoline to improve public health. These improvements are especially needed to protect the health of EJ communities, who experience higher exposures to motor vehicle pollution and are at greatest risk from their effects.

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[93] Kazemiparkouhi F, MacIntosh D, Suh H, Clark N. 2022. Potential Air Quality and Public Health Benefits of Real-World Ethanol Fuels. Letter.

[94] Kazemiparkouhi et al. 2021a.

[95] Ibid.

[96] Kazemiparkouhi et al. 2021b.

[97] Karavalakis G, Short D, Vu D, Russell RL, Asa-Awuku A, Jung H, Johnson KC, Durbin TD. 2015. 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, pp.168-179.

[98] Tang T, Karavalakis G, Johnson K, Durbin T. 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. 32nd. CRC Real World Emissions Workshop. San Diego, CA.

[99] 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.

[100] 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.

[101] 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.

[102] 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.

[103] USEPA 2019. Integrated Science Assessment for Particulate Matter. Center for Public Health and Environmental Assessment.

[104] 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 US Medicare beneficiaries. *Environmental Health*, 19(1), pp.1-12.

## CONCLUSION

The ICCT peer review offers numerous comments on the GTAP-BIO-ADV model and CCLUB default EF used by numerous analysts to estimate iLUC associated with demand for corn starch ethanol and which form the foundation of the iLUC emission rate proposed by WDE. Their comments do not incorporate scientific writings and perspectives of subject matter experts other than those who are critical of this approach. In this letter, we summarized key elements of the views held by those other subject matter experts on the subjects raised by ICCT with the aim of providing WDE a more complete picture of the state of the science for estimation of iLUC emissions. We also present herein our own analysis which demonstrates that uncertainty of iLUC emission estimates, while still present, has decreased over time in step with advancements in methodology and presently is no greater for iLUC than other parameters that are important to protection of human health and resources.

As experienced environmental scientists, engineers, and analysts ourselves, we of course recognize both strengths and weaknesses in GTAP-BIO-ADV and CCLUB EF in comparison to alternative approaches to estimation of iLUC. But more importantly in our view, we also recognize that the iLUC emission rate estimated through GTAP-BIO-ADV and CCLUB EF is highly consistent with estimates from the leading alternative modeling systems – FAPRI, MIRAGE, and GLOBIOM – as described in the first section of this letter. This consistent set of results is strikingly different from estimates generated by earlier, less complete, less tested versions of the same modeling systems. Moreover, the updates made to the modeling systems are rational, explained clearly, and documented in the peer-reviewed and gray scientific literature. The consistency in results observed among current modeling systems is particularly important because replication is a hallmark of reliable science. In our scientific judgement, these characteristics of the iLUC emission rate proposed by WDE outweigh the limitations of GTAP-BIO-ADV and CCLUB default EF posited by ICCT.

Enclosures
Attachment A— Kazemiparkouhi F, MacIntosh D, Suh H, Clark N. 2022. Potential Air Quality and Public Health Benefits of Real-World Ethanol Fuels.

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# Potential Air Quality and Public Health Benefits of Real-World Ethanol Fuels

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## Introduction

For over twenty years, ethanol has been used as a fuel additive in gasoline to boost octane without the harmful impacts on the environment posed by previous fuel additives such as MTBE and lead. While ethanol's benefits to groundwater and lead contamination are well established, uncertainty remains regarding the impacts of ethanol on air quality and public health based on existing literature. This uncertainty largely results from the previous lack of studies that have been conducted using fuels that reflect the actual or real-world composition of gasoline with differing ethanol content.

This document addresses this uncertainty by providing new scientific evidence of the air quality and public health benefits provided by higher ethanol blends. We specifically present findings from our two recent studies, which characterized ethanol blending effects on light duty vehicle regulated emissions of criteria air pollutants[1] and air toxics. Findings from these studies demonstrate ethanol-associated reductions in emissions of key air pollutants and by extension, provide further evidence of the potential for ethanol-blended fuels to improve air quality and public health, particularly for environmental justice communities.

## Impact of Ethanol-Containing Fuels on Air Pollutant Emissions

Kazemiparkouhi et al. (2022a) and Kazemiparkouhi et al. (2022b) 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, including PM, NOx, CO, and THC (Kazemiparkouhi et al., 2022a), as well as BTEX (benzene, toluene, ethylbenzene, xylene) and 1,3-butadiene (Kazemiparkouhi et al., 2022b). In each study, we used similar approaches. We extracted data from a comprehensive set of emissions and market fuel studies conducted in the US. Using these data, we (1) estimated composition of market fuels for different ethanol volumes and (2) developed regression models to estimate the impact of changes in ethanol volumes in market fuels on air pollutant emissions for different engine types and operating conditions. Importantly, our models estimated these changes accounting for not only ethanol

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[1] https://doi.org/10.1016/j.scitotenv.2021.151426

volume fraction, but also aromatic volume fraction, 90% volume distillation temperature (T90) and Reid Vapor Pressure (RVP). Further, our models examined the impacts of ethanol fuels on emissions under both cold start and hot stabilized running conditions and for gasoline-direct injection engines (GDI) and port-fuel injection (PFI) engine types. In doing so, our two papers provided important new information about real-world market fuels and their corresponding air pollutant emissions, as highlighted below.

- ***Aromatic levels in market fuels decreased by ~7% by volume for each 10% by volume increase in ethanol content*** (Table 1)**.** Our findings of lower aromatic content with increasing ethanol content are consistent with market fuel studies by EPA and others, and with octane blending studies (Anderson et al., 2010, Anderson et al., 2012, Stratiev et al., 2017, US EPA, 2017). As discussed in EPA's Fuel Trends Report, for example, ethanol volume in market fuels increased by approximately 6.66% between 2006 and 2016, while aromatics over the same time period were found to drop by 5.4% (US EPA, 2017).

  We note that our estimated market fuel properties differ from those used in the recent US EPA Anti-Backsliding Study (ABS), which examined the impacts of changes in vehicle and engine emissions from ethanol-blended fuels on air quality (US EPA, 2020). Contrary to our study, ABS was based on fuels with targeted properties that were intended to satisfy experimental considerations rather than mimic real-world fuels. It did not consider published fuel trends; rather, the ABS used inaccurate fuel property adjustment factors in its modeling, reducing aromatics by only 2% (Table 5.3 of ABS 2020), substantially lower than the reductions found in our paper and in fuel survey data (Kazemiparkouhi et al., 2022a, US EPA, 2017). As a result, ABS's findings and their extension to public health impacts are not generalizable to real world conditions.

**Table 1. Estimated market fuel properties**

| Fuel ID | EtOH Vol (%) | T50 ($^oF$) | T90 ($^oF$) | Aromatics Vol (%) | AKI | RVP (psi) |
|---|---|---|---|---|---|---|
| E0 | 0 | 219 | 325 | 30 | 87 | 8.6 |
| E10 | 10 | 192 | 320 | 22 | 87 | 8.6 |
| E15 | 15 | 162 | 316 | 19 | 87 | 8.6 |
| E20 | 20 | 165 | 314 | 15 | 87 | 8.6 |
| E30 | 30 | 167 | 310 | 8 | 87 | 8.6 |

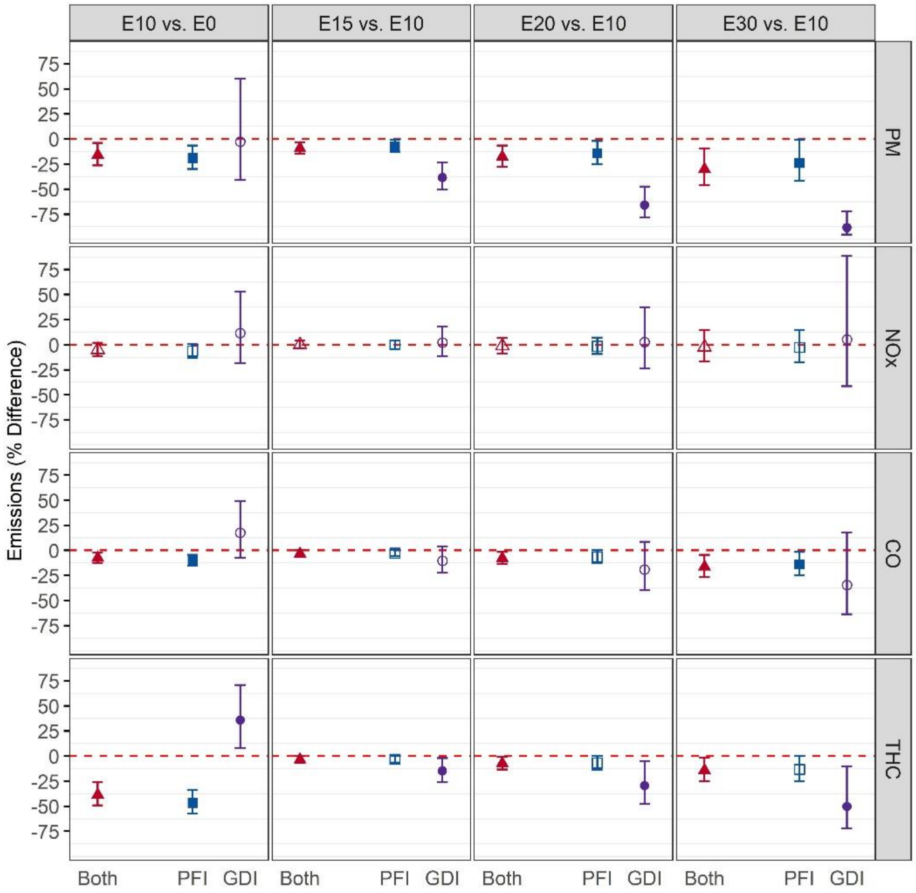
**Abbreviations:** EtOH = ethanol volume; T50 = 50% volume distillation temperature; T90 = 90% volume distillation temperature; Aromatics=aromatic volume; AKI = Anti-knock Index; RVP = Reid Vapor Pressure.

- ***PM emissions decreased with increasing ethanol content under cold-start conditions.*** Primary PM emissions decreased by 15-18% on average for each 10% increase in ethanol content under cold-start conditions (Figure 1). While statistically significant for both engine types, PM emission reductions were larger for GDI as compared to PFI engines, with 88% and 24% lower PM emissions, respectively, when engines burned E30 as compared to E10. In contrast, ethanol content in market fuels had no association with PM emissions during hot-running conditions.

Importantly, our findings are consistent with recent studies that examined the effect of ethanol blending on light duty vehicle PM emissions. Karavalakis et al. (2014), (2015), Yang et al. (2019a), (2019b), Schuchmann and Crawford (2019), for example, assessed the influence of different mid-level ethanol blends – with proper adjustment for aromatics – on the PM emissions from GDI engines and Jimenez and Buckingham (2014) from PFI engines. As in our study, which also adjusted for aromatics, each of these recent studies found higher ethanol blends to emit lower PM as compared to lower or zero ethanol fuels. Our findings of PM reductions are also consistent with recently published studies, for example from a California Air Resources Board (CARB) study (Karavalakis et al., 2022, Tang et al., 2022) that assessed the impact of splash-blending E10 to E15 on PM and other air pollutant emissions for late model year vehicles (2016-2021). The CARB study found a 16.6% reduction in cold start PM in comparison to a 23% PM reduction for E15S versus E10 in our study.

Together, our findings support the ability of ethanol-blended fuels to offer important PM emission reduction opportunities. Cold start PM emissions have consistently been shown to account for a substantial portion of all direct tailpipe PM emissions from motor vehicles, with data from the EPAct study estimating this portion to equal 42% (Darlington et al., 2016, US EPA, 2013). The cold start contribution to total PM vehicle emissions, together with our findings of emission reductions during cold starts, suggest that a ***10% increase in ethanol fuel content from E10 to E20 would reduce total tailpipe PM emissions from motor vehicles by 6-8%.***

**Figure 1**. Change (%) in cold-start emissions for comparisons of different ethanol-content market fuels[a]

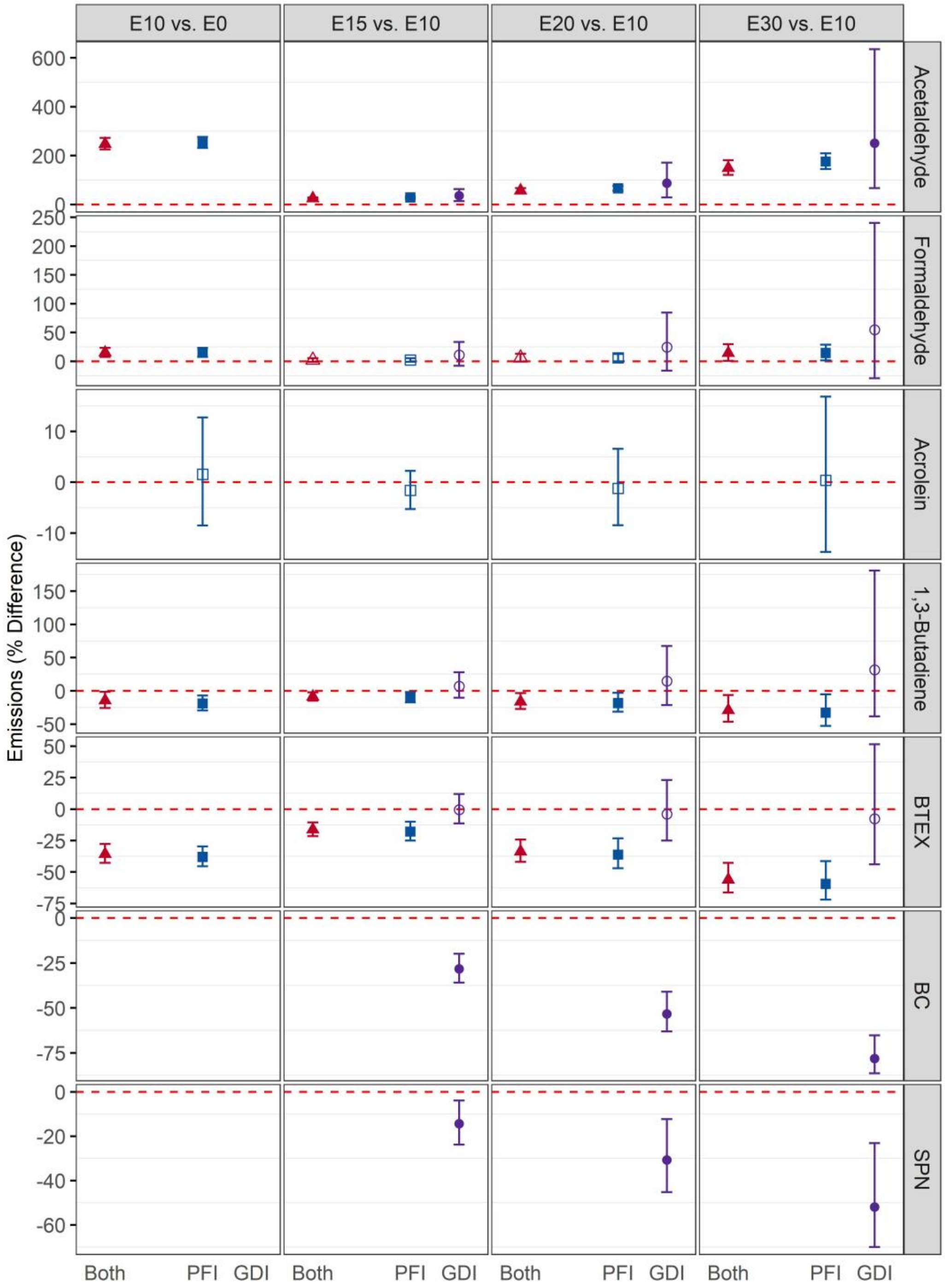


[a] Emissions were predicted from regression models that included ethanol and aromatics volume fraction, T90, and RVP as independent variables (Kazemiparkouhi et al., 2022a)

- ***Emissions of CO and THC generally decreased with increasing ethanol fuel content under cold running conditions, while NOx emissions did not change*** **(**Figure 1). The magnitude of the decrease in CO and THC emissions were comparable to those from the CARB-sponsored Karavalakis et al. (2022) study, which also found significant reductions in cold start THC and CO emissions for splash blended E15, with reductions of 6.1% and 12.1%, respectively. Under hot running conditions, CO, THC and NOx emissions were comparable for each of the examined ethanol fuels. Together, these findings add to the scientific evidence demonstrating emission reduction benefits of ethanol fuels for PM that are achieved with no concomitant increase in emissions for CO, THC, and NOx.

- ***Air toxic emissions showed lower BTEX, 1-3 butadiene, black carbon, and particle number emissions with increasing ethanol content*** in summer market fuels (Figure 2). Acrolein emissions did not vary with ethanol fuel content, while formaldehyde emissions showed little to no significant change with increasing ethanol fuel content. As expected, emissions of acetaldehyde, produced directly from ethanol combustion, increases with ethanol content. Notably, our findings are similar to those from the CARB study of splash-blended fuels (Karavalakis et al., 2022), for which ethylbenzene and xylene were significantly reduced by ~10% for splash-blended E15 (No significant change for Benzene and Toluene).

**Figure 2**. Change (%) in cumulative run toxics emissions for comparisons of different ethanol-content market fuels[a]



[a] Emissions were predicted from regression models that included ethanol and aromatics volume fraction, T90, and RVP as independent variables (Kazemiparkouhi et al., 2022a)
SPN = Solid Particle Number

## Implications for Public Health and Environmental Justice Communities

***The estimated reductions in air pollutant emissions, particularly of PM, indicate that increasing ethanol content offers opportunities to improve air quality and public health.*** As has been shown in numerous studies, lower PM emissions result in lower ambient PM concentrations and exposures (Kheirbek et al., 2016, Pan et al., 2019), which, in turn, are causally associated with lower risks of total mortality and cardiovascular effects (Laden et al., 2006, Pun et al., 2017, US EPA, 2019, Wang et al., 2020).

***The above benefits to air quality and public health associated with higher ethanol fuels may be particularly great for environmental justice (EJ) communities.*** EJ communities are predominantly located in urban neighborhoods with high traffic density and congestion and are thus exposed to disproportionately higher concentrations of PM emitted from motor vehicle tailpipes (Bell and Ebisu, 2012, Clark et al., 2014, Tian et al., 2013). Further, vehicle trips within urban EJ communities tend to be short in duration and distance, with approximately 50% of all trips in dense urban communities under three miles long (de Nazelle et al., 2010, Reiter and Kockelman, 2016, US DOT, 2010). As a result, a large proportion of urban vehicle operation occurs under cold start conditions (de Nazelle et al., 2010), when PM emissions are highest. Given the evidence that ethanol-blended fuels during cold-start conditions substantially reduce PM, CO, and THC emissions while keeping NOx emissions constant, it follows that ethanol-blended fuels may represent an effective method to reduce PM health risks for EJ communities.

## Summary

Findings from Kazemiparkouhi et al. (2022a, 2022b) provide important, new evidence of ethanol-related reductions in vehicular emissions of PM, CO, and THC based on real-world fuels and cold-start conditions. Recent experimental data from CARB studies reinforce this evidence. Given the substantial magnitude of the emission reductions and their potential to improve air quality and through this public health, our findings demonstrate the potential for policies that encourage higher concentrations of ethanol in gasoline to improve public health. These improvements are especially needed to protect the health of EJ communities, who experience higher exposures to motor vehicle pollution and are at greatest risk from their effects.

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