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Clerks' Office
California Air Resources Board
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Submitted online via: http://www.arb.ca.gov/lispub/comm/bclist.php

RE: COMMENTS ON PROPOSED REGIONAL HAZE STATE IMPLEMENTATION PLAN

POET appreciates this opportunity to provide comments in response to CARB's Draft Regional Haze State Implementation Plan (SIP). This Draft Regional Haze SIP builds on California's first plan, which was adopted by CARB's governing board in 2009 and approved by U.S. EPA in 2011. The draft SIP discusses goals to reduce 40 tons per day of NOx emissions by 2028 to mitigate haze and improve visibility in California.[1] POET supports California's efforts to reduce air emissions and hopes to work with the state to reach its air quality goals, and in these comments POET urges CARB to look to bioethanol to help reduce air toxics.

About POET

POET's vision is to create a world in sync with nature. As the world's largest producer of biofuel and a global leader in sustainable bioproducts, POET creates plant-based alternatives to fossil fuels that utilize the regenerative 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 that includes Dakota Gold and NexPro feed, Voilà corn oil, purified alcohol, renewable CO2 and JIVE asphalt rejuvenator, POET is committed to innovation and advancing powerful, practical solutions to some of the world's most pressing challenges. Today, POET holds more than 80 patents worldwide 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.

Bioethanol Air Toxics Emissions Reductions

The draft SIP discusses strategies to reduce NOx from mobile sources. The studies discussed in this section of our comment show that bioethanol either slightly reduces or does not contribute to NOx emissions. Additionally, bioethanol provides a pathway to reduce other

[1] *Draft California's Regional Haze Plan for the Second Implementation Period*, CARB (May 13, 2022), 10, https://ww2.arb.ca.gov/sites/default/files/2022-05/SecondRegionalHazePlanMainDocumentDRAFT.pdf.

harmful air pollutants such as total hydrocarbons (THCs), carbon monoxide compounds, $PM_{2.5}$,[2] and BTEX.

A recent analysis from leading national experts demonstrates air quality and public health benefits from higher biofuel blends.[3] The study is the first large-scale analysis of data from light-duty vehicle emissions that examines real-world impacts of ethanol-blended fuels on regulated air pollutant emissions, including particulate matter (PM), carbon monoxide (CO), NOx, and THCs. The study found that CO and THC emissions were significantly lower for higher ethanol fuels for port fuel injected engines under cold-start conditions. THCs include VOCs, meaning that both primary ozone precursors decreased with higher ethanol blends. The study found no statistically significant relationship between higher ethanol blends and NOx emissions.

Another recent analysis builds on that work, demonstrates ethanol-associated reductions in emissions of primary PM, CO, and THCs, and shows that health benefits from ethanol should apply to disadvantaged communities in particular.[4] Key findings of the study include:

- PM emissions decreased with increasing ethanol content under cold-start conditions. Primary PM emissions decreased by 15-19 percent on average for each 10 percent increase in ethanol content under cold-start conditions. Cold start PM emissions have consistently been shown to account for a substantial portion of all direct tailpipe PM emissions from motor vehicles. 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.
- Emissions of CO and THC generally decreased with increasing ethanol fuel content under cold running conditions, while NOx emissions did not change.
- Air toxic emissions showed lower BTEX, 1-3 butadiene, black carbon, and particle number emissions with increasing ethanol content in market fuels.
- Higher blends of ethanol fuels may be particularly beneficial for disadvantaged communities that have high traffic density and congestion and are thus exposed to disproportionately higher concentrations of PM emitted from motor vehicle tailpipes. Vehicle trips within these communities tend to be short in duration and distance, with approximately 50% of all trips in dense urban communities under three miles long. As a result, a large proportion of these vehicle trips occur under cold start conditions when PM emissions are highest.

The air quality benefits demonstrated in these studies show that biofuel can play a key role in helping CARB meet state climate goals and achieve federal and state air quality standards.

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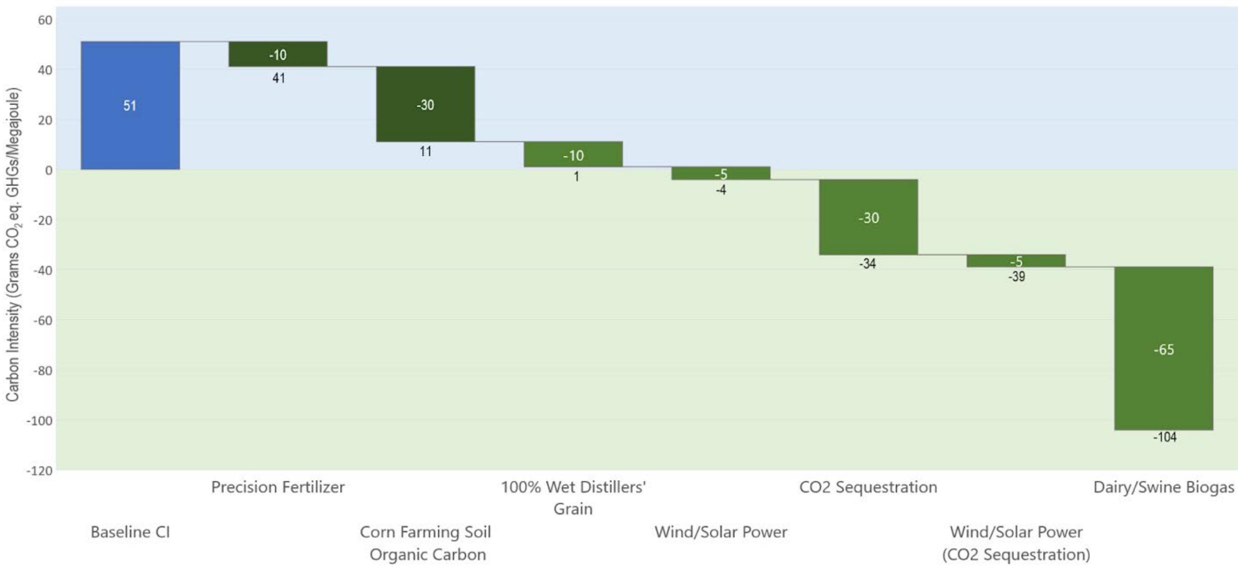
[2] Kazemiparkouhi, Fatemeh *et al., Comprehensive US Database and Model for Ethanol Blend Effects on Regulated Tailpipe Emissions*, Atmospheric Environment, Under Review.
[3] *See id*.
[4] *See* Attachment A, Tufts University Department of Civil and Environmental Engineering, *Air Quality and Public Health Comments to RFS*, February 3, 2022.

Bioethanol's GHG Emissions Benefits

In addition to the air quality benefits discussed above, recent studies show corn starch bioethanol's carbon intensity (CI) is 46% lower than that of gasoline.[5] With technologies already being implemented or on the cusp of commercialization, bioethanol has the ability to become a zero-carbon fuel. The chart below compares bioethanol's CI score to a gasoline baseline and shows technologies, many of which POET has already implemented and others which the company is evaluating, that would allow bioethanol to become a zero-carbon fuel:



Innovations across the biofuel production lifecycle have resulted in increasingly cleaner liquid biofuels. These innovations will only continue to drive down the CI of conventional and advanced biofuels.

Planning for the Cleanest Possible Legacy Vehicle Fleet in California

California will have a significant fleet of internal combustion vehicles on its roads for decades. Under current scenarios, vehicles powered by fossil fuels will continue to dominate new car sales in the state for the foreseeable future, even as California works to achieve its goal pursuant to Executive Order N-79-20 that all new passenger vehicles sold be zero-emission by 2035. Even if the state successfully achieves this goal, millions of internal combustion engine-powered vehicles will be driven on California's roads well after 2035.

To meet and maintain climate and air quality goals in the future, it is imperative that CARB start planning now for achieving the maximum amount of emission reductions from existing cars and trucks by developing rules that will equip them to run on increasingly clean liquid fuels like advanced biofuel and renewable gasoline that can displace fossil fuel.

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[5] Sully, Melissa *et al.*, *Carbon Intensity of Corn Ethanol in the United States: State of the Science*, 2021 Environ. Res. Lett 16 043001, 4, 14 (2021), https://iopscience.iop.org/article/10.1088/1748-9326/abde08.

Technologies like renewable gasoline and advanced biofuel with carbon capture and sequestration – both of which POET is actively exploring – can deliver zero and negative carbon intensity solutions in the transportation sector. CARB should ensure that the Regional Haze SIP considers and supports these technologies as all approaches to transportation emissions reductions will be needed to meet the state's climate and air quality goals.

*   *   *

POET strongly supports California's efforts to reduce air toxics and GHG emissions. We appreciate CARB's consideration of these comments and look forward to engaging in a productive dialogue with the agency on the Regional Haze SIP and the role biofuels play in helping California achieve its emissions reduction goals. If you have any questions, please contact me at Matt.Haynie@POET.COM or (202) 756-5604.

Sincerely,

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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

[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 summer 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

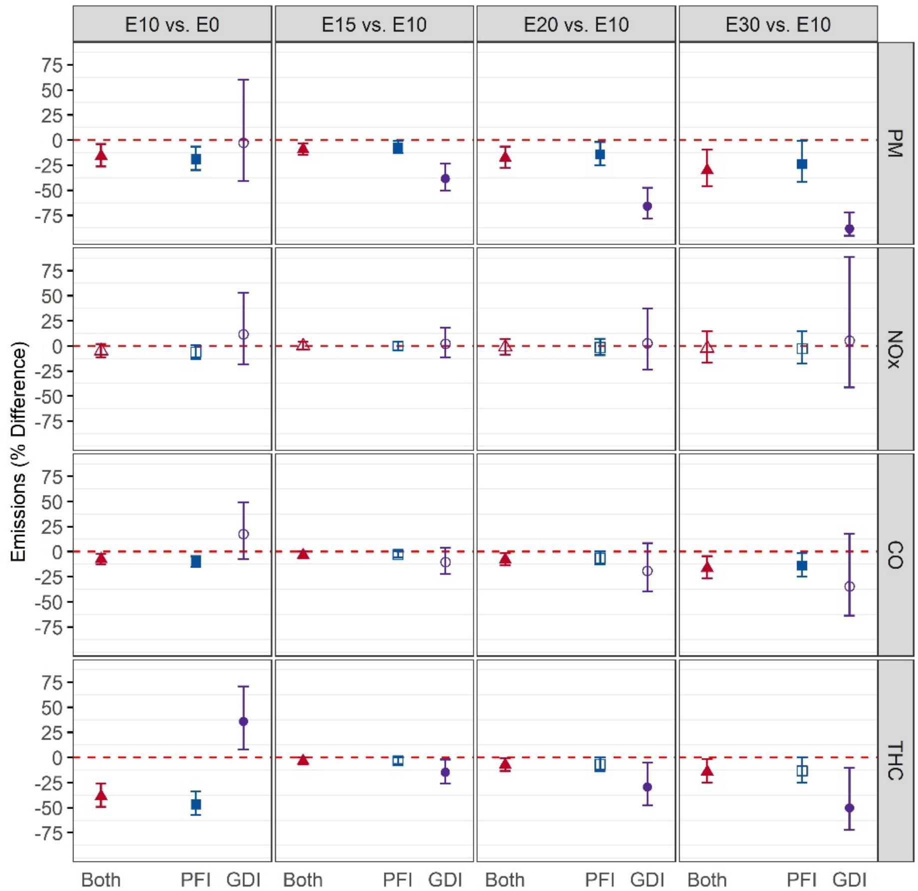
Abbreviations: EtOH = ethanol volume; T50 = 50% volume distillation temperature; T90 = 90% volume distillation temperature; Aromatics=aromatic volume; AKI = Anti-knock Index; RVP = Reid Vapor Pressure.

- ***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). 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 summer market fuels[a]

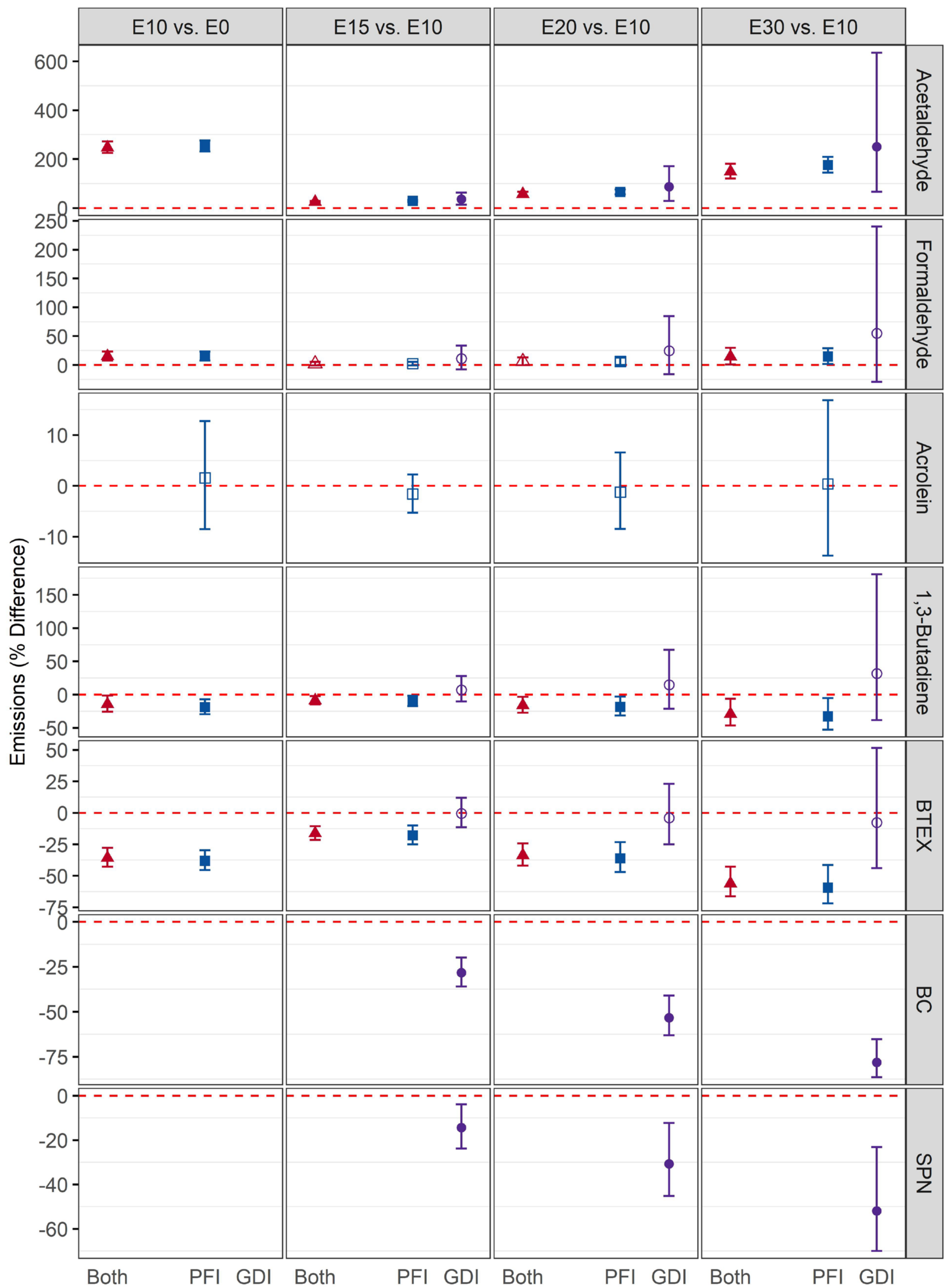


[a] Emissions were predicted from regression models that included ethanol and aromatics volume fraction, T90, and RVP as independent variables (Kazemiparkouhi et al., 2022a)

- ***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 fuel content*** (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 summer 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

The general pattern for cold-start and hot-running emissions of winter regular and summer premium fuels is in sympathy with the results for the summer fuel.

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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