Appendix B.

Multimedia Working Group Agency Evaluations

- California Air Resources Board: Impact Assessment of E15 on Exhaust and Evaporative Emissions From Light-Duty Vehicles
- State Water Resources Control Board: E15 Multimedia Evaluation
- Office of Environmental Health Hazard Assessment: The Potential for Toxicity of E15 versus E10 Exhausts
- Department of Toxic Substances Control: Recommendation on E15 Multimedia Evaluation

California Air Resources Board: Impact Assessment of E15 on Exhaust and Evaporative Emissions from Light-Duty Vehicles

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State of California
California Air Resources Board

Impact Assessment of E15 on Exhaust and Evaporative Emissions from Light-Duty Vehicles

September 2025

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1. INTRODUCTION

The California Air Resources Board (CARB) is considering the development of new fuel specifications for 15 percent ethanol by volume (E15).

Before new fuel specifications can be established, California Health and Safety Code (HSC) section 43830.8 requires a multimedia evaluation to be conducted and reviewed by the California Environmental Policy Council (CEPC). A "multimedia evaluation" is the identification and evaluation of any significant adverse impact on public health or the environment, including air, water, or soil, that may result from the production, use, or disposal of the motor vehicle fuel that may be used to meet the state board's motor vehicle fuel specifications.[1]

This report provides staff's assessment of the emissions data and air quality impact information obtained during the E15 multimedia evaluation and staff's overall conclusions and recommendations to the CEPC. Staff's assessment is based on the data and information provided in the E15 multimedia evaluation, including the multimedia reports (Final Tier I, Tier II and Tier III Reports) by Growth Energy and the Renewable Fuels Association; the *"Comparison of Exhaust Emissions Between E10 CaRFG and Splash Blended E15"* (Exhaust Emissions Study)[2] by the University of California, Riverside (UCR), College of Engineering – Center for Environmental Research and Technology (CE-CERT) and the *"Comparison of Evaporative Emissions Between E10 CaRFG and Splash Blended E15"* (Evaporative Emissions Study)[3] by the Automotive Testing and Development Services, Inc (ATDS).

A. Multimedia Evaluation of E15

Pursuant to HSC section 438030.8, Growth Energy and Renewable Fuels Association (known as the "Fuel Applicants"), conducted a multimedia evaluation of E15 fuel ethanol compared to California reformulated gasoline, which is 10 percent ethanol by volume (E10) that meets the California Reformulated Gasoline Regulations (Gasoline Regulations).[4] The proposed fuel specifications define E15 as being composed of fuel grade denatured ethanol, pursuant to

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[1] California Air Pollution Control Laws. Health and Safety Code, Division 26, Part 5, Chapter 4, Section 43830.8(b). *https://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?sectionNum=43830.8.&lawCode=HSC*.

[2] Karavalakis, G., Durbin T.D., & Tang, T. *Comparison of Exhaust Emissions Between E10 CaRFG and Splash Blended E15.* June 2022. *https://ww2.arb.ca.gov/sites/default/files/2022-07/E15_Final_Report_7-14-22_0.pdf*.

[3] Automotive Testing and Development Services, Inc. *Comparison of Evaporative Emissions Between E10 CaRFG and Splash Blended E15.* January 2022.

[4] California Air Resources Board. California Reformulated Gasoline Regulations. Title 13, California Code of Regulations, Sections 2250-2273.5. *https://ww2.arb.ca.gov/resources/documents/california-reformulated-gasoline-regulations*.

ASTM D4806,[5] and either California Reformulated Gasoline Blendstock for Oxygenate Blending (CARBOB) or finished fuel California reformulated gasoline (CaRFG) for the hydrocarbon fraction. The Gasoline Regulation defines CARBOB as "petroleum-derived liquid, which is intended to be, or is represented as, a product that will constitute California gasoline upon the addition of a specified type and percentage (or range of percentages) of oxygenate to the product after the product has been supplied from the production or import facility at which it was produced or imported."[6]

As specified in HSC section 43830.8, the multimedia evaluation shall be based on the best available scientific data, written comments, and any information collected by CARB in preparation for the proposed rulemaking. A multimedia evaluation consists of three tiers. Tier I begins with a summary of what is known about the fuel and the information needed for the multimedia risk assessment. The Tier I Report identifies key knowledge gaps about the fuel, if any, and establishes the overall scope of the evaluation. Tier II is the development of the Tier II Report, or Risk Assessment Protocol, to fill in any knowledge gaps identified during Tier I. If key knowledge gaps are not identified in Tier I, no further Tier II testing or information is needed, and the multimedia evaluation would then proceed directly to Tier III. Tier III is the implementation of the risk assessment, resulting in a final report of any significant adverse impact on public health or the environment. The multimedia evaluation process is summarized in Figure 2.1 of the "*Fuels Multimedia Evaluation Guidance Document*."[7] After each tier of the evaluation process, the Fuel Applicants submitted a tier report for review and approval by the Multimedia Working Group (MMWG). The final reports are listed below:

- California Multimedia Evaluation of E11-E15 Gasoline-Ethanol Blends Tier I Report (Final Tier I Report)[8]
- California Multimedia Evaluation of E11-E15 Gasoline-Ethanol Blends Tier II Report (Final Tier II Report)[9]

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[5] ASTM International. *ASTM D4806. Standard Specification for Denatured Fuel Ethanol Blending with Gasoline for Use as an Automotive Spark-Ignition Engine Fuel*. Oct 19, 2021.

[6] California Code of Regulations. Title 13, Section 2260(a)(6.5). https://ww2.arb.ca.gov/sites/default/files/2020-05/California_Reformulated_Gasoline_Regulations_2-16-14.pdf.

[7] University of California, Berkeley; University of California, Davis. *Guidance on the Types of Scientific Information to be Submitted by Applicants for California Fuels Environmental Multimedia Evaluations*. March 2016. Page 16. https://ww2.arb.ca.gov/resources/documents/fuels-multimedia-evaluation-guidance-document.

[8] Renewable Fuels Association, Growth Energy. *California Multimedia Evaluation of E11-E15 Gasoline-Ethanol Blends: Tier I Report.* June 4, 2020. California Multimedia Evaluation of E11 - E15 Gasoline-Ethanol Blends Tier I Report.

[9] Renewable Fuels Association, Growth Energy. *California Multimedia Evaluation of E11-E15 Gasoline-Ethanol Blends: Tier II Report.* July 24, 2023. ww2.arb.ca.gov/sites/default/files/2025-03/E15_MME_Tier_II_Report_July_2023.pdf.

- California Multimedia Evaluation of E11-E15 Gasoline-Ethanol Blends Tier III Report (Final Tier III Report)[10]

During Tier I of the E15 evaluation, the Fuel Applicants completed a detailed review of E15, evaluated potential impacts, and determined key knowledge gaps. Upon completion of Tier I, the overall scope of the E15 evaluation was established. The knowledge gaps identified in Tier I necessitated further study, testing and a more detailed impact assessment of E15 in Tier II. The E15 Tier II risk assessment design included exhaust and evaporative emissions studies to fill in key knowledge gaps identified in Tier I. Tier III began with the implementation of the Tier II risk assessment protocols and concluded with the formal submittal of the E15 Final Tier III Report.

Based on the E15 multimedia evaluation and the information provided in the Final Tier I, Tier II and Tier III reports, the MMWG determined that the use of E15, as specified in this multimedia evaluation and the proposed fuel specifications, does not pose a significant adverse impact on public health nor the environment compared to E10.

B. Emissions Testing Program

Exhaust and evaporative emissions testing were conducted to determine the emissions impacts of E15 fuel ethanol compared to E10 gasoline that meets the Gasoline Regulations.

Exhaust emissions testing was performed on twenty light-duty gasoline vehicles of various makes, models, technology standards and sizes. In general, the results from the Exhaust Emissions Study found that most regulated emissions from E15 are reduced compared to E10, including particulate matter (PM) mass, carbon monoxide (CO), and total hydrocarbons (THC). Nitrogen oxides (NOx) did not show any statistically significant differences between E15 and E10.

Evaporative emissions testing was conducted on a subset of the vehicles tested in the Exhaust Emissions Study, including a 2016 Nissan Rogue, 2020 Jeep Cherokee, 2019 RAV4, and a 2021 Hyundai Accent.[11] In general, evaporative emissions results did not show any statistically significant differences between E15 and E10.

2. E15 FUEL ETHANOL

E15 is a gasoline fuel blend of 15 percent ethanol and 85 percent gasoline. The E15 fuel blends that were studied in this evaluation were produced by splash blending denatured

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[10] Renewable Fuels Association, Growth Energy. *California Multimedia Evaluation of E11-E15 Gasoline-Ethanol Blends: Tier III Report*. March 8, 2024.

[11] Automotive Testing and Development Services, Inc. (2022, January). *Comparison of Evaporative Emissions Between E10 CaRFG and Splash Blended E15.*

ASTM D4806[12] fuel grade ethanol with California reformulated gasoline (10 percent ethanol by volume, or E10).

The U.S. Environmental Protection Agency (EPA) defines E15 as gasoline containing more than 10 percent and up to 15 percent ethanol by volume. In 2011, EPA granted partial waivers that allow E15 for use in light-duty conventional vehicles of model year (MY) 2001 and newer, subject to certain conditions.[13]

3. EMISSIONS TESTING

Exhaust and evaporative emissions testing were conducted to determine emissions impacts of E15 compared to E10 meeting Gasoline Regulations.

A. Exhaust Emissions Testing

The E15 Exhaust Emissions Study was conducted at CE-CERT and co-funded by CARB and the ethanol industry. Emissions testing focused primarily on regulated emissions, including NOx, CO, THC, PM mass, carbon dioxide (CO_2), methane (CH_4) and nonmethane hydrocarbons (NMHC). More extensive testing, including toxics analyses, was completed as part of the study.[14]

i. Test Program

For this program, E15 fuel ethanol was tested in comparison to conventional E10 gasoline. E10 and E15 were tested on twenty MY 2016 and newer light-duty vehicles over triplicate Federal Test Procedure (FTP) cycles.

The baseline E10 fuel used for testing was a summer-grade California Reformulated Gasoline sourced from four different refineries selected by CARB. Three refineries were in the South Coast Air Basin (SCAB) and one refinery was in Northern California. The SCAB refineries included PBF Energy (Los Angeles), Phillips 66 (Los Angeles) and Marathon (Wilmington). The Bay Area refinery was Chevron (Richmond). The E10 fuels were blended together in four equal parts to create the final E10 fuel. The E15 test fuel was created by splash blending denatured ASTM D4806 fuel grade ethanol with the final E10 fuel.

Testing was conducted on twenty light-duty vehicles that included a mixture of technologies, including gasoline direct injection (GDI), port fuel injection (PFI) and PFI+GDI fuel systems that are representative of the current California gasoline fleet. One hybrid electric vehicle

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[12] ASTM International. *ASTM D4806. Standard Specification for Denatured Fuel Ethanol Blending with Gasoline for Use as an Automotive Spark-Ignition Engine Fuel*. Oct 19, 2021.

[13] U.S. Environmental Protection Agency. *Final Rule: Regulation to Mitigate the Misfueling of Vehicles and Engines with Gasoline Containing Greater than Ten Volume Percent Ethanol.* https://www.epa.gov/gasoline-standards/final-rule-regulation-mitigate-misfueling-vehicles-and-engines-gasoline. Accessed Dec 24, 2024.

[14] Karavalakis, G., Durbin T.D., & Tang, T. *Comparison of Exhaust Emissions Between E10 CaRFG and Splash Blended E15.* June 2022. https://ww2.arb.ca.gov/sites/default/files/2022-07/E15_Final_Report_7-14-22_0.pdf.

with a PFI engine was also used. All vehicles were equipped with three-way catalysts.[15] Table 1 provides a list of all the vehicles used for testing.[16]

Table 1. Test Vehicles

Vehicle	Year	Make	Model
PFI#1	2019	Dodge	Ram1500
GDI#1	2018	Honda	Fit
PFI#2	2020	Jeep	Compass
PFI#3	2016	Nissan	Rogue
PFI+GDI#1	2019	Toyota	RAV4
GDI#2	2018	Honda	Civic
GDI#3	2016	Mazda	Mazda3
GDI#4	2020	Ford	Fusion
GDI#5	2019	Chevrolet	Impala
PFI#4	2021	Chevrolet	Spark
GDI#6	2020	KIA	Optima
PFI#5	2020	Jeep	Cherokee
GDI#7	2020	Nissan	Armada
PFI_Hybrid#1	2020	Toyota	Prius
GDI#8	2020	GMC	Acadia
GDI#9	2020	Buick	Enclave
GDI#10	2021	Chevrolet	Colorado
PFI+GDI#2	2017	Ford	F-150
PFI#6	2021	Hyundai	Accent
GDI#11	2018	Chevrolet	Suburban

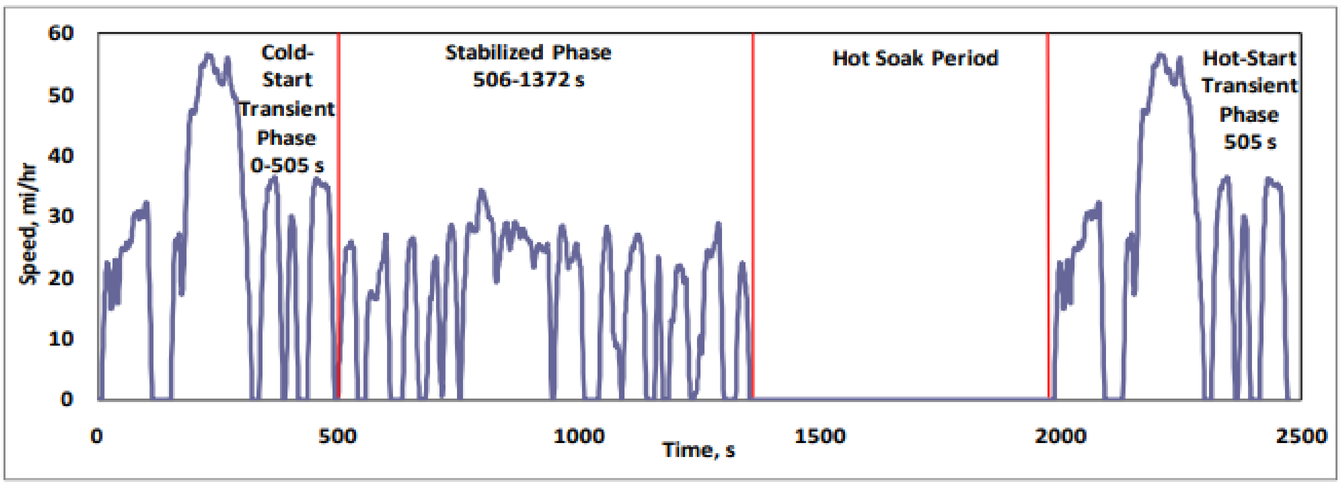
Emissions measurements were conducted in CE-CERT's Light-Duty Laboratory according to U.S. EPA light-duty emissions testing protocols in Title 40, Code of Federal Regulations,

[15] Karavalakis, G., Durbin T.D., & Tang, T. *Comparison of Exhaust Emissions Between E10 CaRFG and Splash Blended E15*. June 2022. *https://ww2.arb.ca.gov/sites/default/files/2022-07/E15_Final_Report_7-14-22_0.pdf*. Page 6.

[16] Karavalakis, G., Durbin T.D., & Tang, T. *Comparison of Exhaust Emissions Between E10 CaRFG and Splash Blended E15*. June 2022. *https://ww2.arb.ca.gov/sites/default/files/2022-07/E15_Final_Report_7-14-22_0.pdf*. Page 8, Table 2-4.

Parts 1065 and 1066.[17,18] Each vehicle and fuel combination was tested using the Federal Test Procedure (FTP) emissions test cycle, which is used for emission certification of light-duty vehicles in the United States. The entire FTP cycle consists of three phases, including a cold-start transient phase (0 to 505 seconds), a stabilized or hot-running phase (506 to 1,372 seconds), a hot sock period with the engine off (9 to 10 minutes), and a hot-start transient phase (0 to 505 seconds). The FTP has a duration of 1,877 seconds, a distance of 11.04 miles, an average speed of 21.2 miles per hour (mph), and maximum speed of 56.7 mph. The FTP test cycle is shown in Figure 1.[19]

Figure 1. FTP Cycle



Gravimetric PM mass samples were collected for each of the three individual phases of the FTP (i.e., cold-start, hot-running, and hot-start) and weighted PM mass over the entire FTP cycle was calculated based on PM mass data from each phase of the FTP. Carbonyl compounds (aldehydes and ketones) were sampled on 2,4-dinitrophenylhydrazine coated silica cartridges using a mass flow controller to regulate the flow through the cartridge. Hydrocarbon species and ethanol were collected using a passivated canister. Analysis of the hydrocarbon species was conducted using a Gas Chromatography/Mass Spectrometry/Flame Ionization Detector analytical system according to the EPA TO-12/PAMS

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[17] Code of Federal Regulations. 2025. *Title 40, Chapter I, Subchapter U, Part 1065: Engine-Testing Procedures.* Accessed January 23, 2025. *https://www.ecfr.gov/current/title-40/chapter-I/subchapter-U/part-1065?toc=1*.

[18] Code of Federal Regulations. 2025. *Title 40, Chapter I, Subchapter U, Part 1066: Vehicle-Testing Procedures.* Accessed January 23, 2025. *https://www.ecfr.gov/current/title-40/chapter-I/subchapter-U/part-1066?toc=1*.

[19] Karavalakis, G., Durbin T.D., & Tang, T. *Comparison of Exhaust Emissions Between E10 CaRFG and Splash Blended E15.* June 2022. *https://ww2.arb.ca.gov/sites/default/files/2022-07/E15_Final_Report_7-14-22_0.pdf*. Page 9, Figure 2-1.

and EPA TO-15A methods.[20] Nitrous oxide (N_2O) and ammonia (NH_3) emissions were measured at the tailpipe using a Fourier Transform Infrared system.[21]

Statistical analyses for each pollutant were run using the mixed procedure in PC/SAS from SAS Institute, Inc.[22] Mixed models are a type of model that include both fixed and random factors. For this study, the fuel type was treated as a fixed factor in the model while the vehicles were treated as a random factor.[23]

ii. Results

The results below are from the Exhaust Emissions Study. Results are considered "statistically significant" if the associated p-values are less than 0.05, which represent a 95 percent confidence level. Results are considered "marginally statistically significant" if the associated p-values are greater than or equal to 0.05 and less than 0.1.

1. Health-Relevant Air Emissions

Emissions testing conducted as part of the Exhaust Emissions Study focused primarily on regulated emissions, including NOx, CO, THC, PM, CO_2, CH_4 and NMHC. More extensive testing, including toxics analyses, was completed as part of the study. Table 2 provides the Exhaust Emissions Study results.[24] The percent differences for E15 relative to E10 are provided, along with the associated p-values for statistical comparisons.

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[20] U.S. Environmental Protection Agency. Method TO-12. *Method for the Determination of Non-Methane Organic Compounds (NMOC) In Ambient Air Using Cryogenic Preconcentration and Direct Flame Ionization Detection (PDFID)*. Method TO-15A. *Determination of Volatile Organic Compounds (VOCs) in Air Collected in Specially Prepared Canisters and Analyzed by Gas Chromatography-Mass Spectrometry (GC-MS)*. September 2019. *https://www.epa.gov/amtic/compendium-methods-determination-toxic-organic-compounds-ambient-air*.

[21] Karavalakis, G., Durbin T.D., & Tang, T. *Comparison of Exhaust Emissions Between E10 CaRFG and Splash Blended E15.* June 2022. *https://ww2.arb.ca.gov/sites/default/files/2022-07/E15_Final_Report_7-14-22_0.pdf*.

[22] SAS Institute Inc. 2025. *SAS/STAT 9.2 User's Guide: The MIXED Procedure*. Accessed January 23, 2025. *https://support.sas.com/documentation/cdl/en/statug/63033/HTML/default/viewer.htm#mixed_toc.htm*.

[23] Karavalakis, G., Durbin T.D., & Tang, T. *Comparison of Exhaust Emissions Between E10 CaRFG and Splash Blended E15.* June 2022. *https://ww2.arb.ca.gov/sites/default/files/2022-07/E15_Final_Report_7-14-22_0.pdf*. Page v.

[24] Karavalakis, G., Durbin T.D., & Tang, T. *Comparison of Exhaust Emissions Between E10 CaRFG and Splash Blended E15.* June 2022. *https://ww2.arb.ca.gov/sites/default/files/2022-07/E15_Final_Report_7-14-22_0.pdf*.

Table 2. Exhaust Emissions Results

Pollutant	Weighted Emissions*			P-value
	E10	E15	% Difference* *E15 relative to E10*	
NOx	0.00737 g/mi	0.00713 g/mi	- 3%	0.500
THC	0.0161 g/mi	0.0153 g/mi	**- 5%**	0.0216
NMHC	0.0127 g/mi	0.0116 g/mi	- 9%	0.0875
CO	0.333 g/mi	0.277 g/mi	**- 17%**	0.0196
CO_2	343 g/mi	344 g/mi	0.3%	0.779
PM	0.858 mg/mi	0.700 mg/mi	**- 18%**	0.0275
1,3-Butadiene	0.0251 mg/mi	0.0252 mg/mi	0.4%	0.919
Benzene	0.871 mg/mi	0.874 mg/mi	0.3%	0.966
Toluene	0.894 mg/mi	0.982 mg/mi	10%	0.551
Ethylbenzene	0.231 mg/mi	0.205 mg/mi	**- 11%**	0.0498
m/p-xylenes	0.739 mg/mi	0.666 mg/mi	- 10%	0.0649
o-xylene	0.254 mg/mi	0.231 mg/mi	- 9%	0.0504
Ethanol	0.468 mg/mi	0.828 mg/mi	**77%**	0.00870
Formaldehyde	0.209 mg/mi	0.226 mg/mi	8%	0.439
Acetaldehyde	0.284 mg/mi	0.373 mg/mi	**32%**	< 0.0001

*Bold values are statistically significant ($p \leq 0.05$); Underlined values are marginally statistically significant ($0.05 < p \leq 0.10$)

Results generally found that most regulated emissions from E15 are reduced compared to E10, including PM, CO and THC. Weighted PM, CO and THC emissions showed a statistically significant reductions of 18%, 17% and 5%, respectively, for E15 compared to E10 across the entire fleet of 20 vehicles. NOx did not show any statistically significant difference between the fuels.[25]

Toxics emissions tests were conducted for various carbonyl compounds and hydrocarbon species, including benzene, toluene, ethylbenzene, m/p-xylenes, o-xylenes (BTEX),

[25] Karavalakis, G., Durbin T.D., & Tang, T. *Comparison of Exhaust Emissions Between E10 CaRFG and Splash Blended E15*. June 2022. https://ww2.arb.ca.gov/sites/default/files/2022-07/E15_Final_Report_7-14-22_0.pdf. Page vi.

1,3-butadiene, formaldehyde, acetaldehyde and ethanol emissions. Toxics results show statistically significant reductions in ethylbenzene (11%) and increases in acetaldehyde (32%) and ethanol (77%). As expected, acetaldehyde and ethanol emissions were consistently higher for E15 compared to E10 as acetaldehyde emissions are a function of ethanol content. Cumulative BTEX emissions results for benzene and toluene did not show any statistically significant differences between E10 and E15. For m/p-xylenes and o-xylene emissions, E15 showed marginally statistically significant reductions of 10% and 9%, respectively. 1,3-butadiene and formaldehyde emissions results did not show any statistically significant difference between E10 and E15.[26]

2. Climate-Relevant Air Emissions

Gases that trap heat in the atmosphere are called greenhouse gases (GHGs). GHG emissions are primarily CO_2, CH_4, nitrous oxide (N_2O), and hydrofluorocarbons.[27] Each of these gases can remain in the atmosphere for different amounts of time, ranging from a few years to thousands of years.[28] GHG emissions from the use of fuels are primarily CO_2.[29]

Weighted CO_2 emission results from the study did not show any statistically significant differences between E10 and E15. In general, any increase in CO_2 emissions would not necessarily suggest that the fuel leads to an overall increase in carbon emissions. Most THC and CO convert to CO_2 in the atmosphere, so total CO_2 produced by the combustion process is determined by direct CO_2 emissions, as well as THC and CO. As previously stated, weighted CO and THC emissions showed a statistically significant reduction of 17% and 5%, respectively, for E15 compared to E10 across the entire fleet of 20 vehicles.[30]

3. Secondary Pollutants

Secondary pollutants form in the atmosphere through chemical and photochemical reactions from other primary pollutants. An example includes ozone, which is formed when hydrocarbons and NOx combine in the presence of light. Its precursor components are

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[26] Karavalakis, G., Durbin T.D., & Tang, T. *Comparison of Exhaust Emissions Between E10 CaRFG and Splash Blended E15.* June 2022. https://ww2.arb.ca.gov/sites/default/files/2022-07/E15_Final_Report_7-14-22_0.pdf. Page 44.

[27] California Air Resources Board. *Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Public Hearing to Consider Adoption of Regulations to Control Greenhouse Gas Emissions from Motor Vehicles.* August 6, 2004. Page i.

[28] United States Environmental Protection Agency. *Overview of Greenhouse Gases* website. https://www.epa.gov/ghgemissions/overview-greenhouse-gases. Accessed November 20, 2024.

[29] California Air Resources Board. *Proposed Re-Adoption of the Low Carbon Fuel Standard. Staff Report: Initial Statement of Reasons.* December 2014, ES-2. https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2015/lcfs2015/lcfs15isor.pdf.

[30] Karavalakis, G., Durbin T.D., & Tang, T. *Comparison of Exhaust Emissions Between E10 CaRFG and Splash Blended E15.* June 2022. https://ww2.arb.ca.gov/sites/default/files/2022-07/E15_Final_Report_7-14-22_0.pdf. Page 54.

primarily the result of road traffic. Unlike many of the other GHGs, ozone is a short-lived gas that is found in regionally varying concentrations.

Both THC and NOx emissions determine ozone concentrations. As previously stated, THC emissions showed statistically significant reductions. NOx did not show any statistically significant difference between E10 and E15.

B. Evaporative Emissions Testing

The Evaporative Emissions Study was conducted at ATDS and funded by the ethanol industry.

i. Test Program

For this program, the same E10 and E15 fuels that were used as part of CE-CERT's Exhaust Emissions Study were used in this study. The fuels were supplied by CE-CERT and delivered to ATDS in drums.

Five test vehicles were selected from the larger group of twenty that were tested under the Exhaust Emissions Study at CE-CERT, including a 2016 Nissan Rogue, 2019 Toyota RAV4, 2020 Jeep Cherokee, 2020 Jeep Compass, and a 2021 Hyundai. However, the 2020 Jeep Compass failed to complete emissions testing. Both E15 tests were aborted before completion due to potential vehicle failure.[31]

Evaporative emissions testing at ATDS followed the test procedures in the *California Evaporative Emissions Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles* except for the running loss test that was not included as part of the testing. [32]

ii. Results

Results from the Evaporative Emissions Study did not show any statistically significant differences between E10 and E15. A paired t-test was conducted as part of the statistical analysis of the results. Table 4 provides a summary of the results.[33]

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[31] Automotive Testing and Development Services, Inc. *Evaporative Emissions Testing*. Project Number 3081-170527. Page 5.

[32] Automotive Testing and Development Services, Inc. *Comparison of Evaporative Emissions Between E10 CaRFG and Splash Blended E15*. January 2022. Section 1.2

[33] Automotive Testing and Development Services, Inc. *Comparison of Evaporative Emissions Between E10 CaRFG and Splash Blended E15*. January 2022. Section 1.5.

Table 4. Evaporative Emissions Results (grams)

Vehicle	E10	E15	Statistically Significant?
Toyota RAV4	0.203	0.226	No
Nissan Rogue	1.066	0.667	No
Jeep Cherokee	0.811	0.610	No
Hyundai Accent	0.231	0.345	No

4. SUMMARY, CONCLUSIONS and RECOMMENDATIONS

A. Summary

i. Health-Relevant Air Emissions

Results from the Exhaust Emissions Study generally found that most emissions from E15 are reduced compared to E10, including PM, THC and CO. Weighted PM, THC, and CO emissions showed a statistically significant reduction of 18%, 17% and 5%, respectively, for E15 compared to E10 across the entire fleet of 20 vehicles. NOx did not show any statistically significant difference between the fuels.

Cumulative BTEX emissions results for benzene and toluene did not show any statistically significant differences between E10 and E15. For ethylbenzene 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. 1,3-butadiene and formaldehyde emissions results did not show any statistically significant difference between fuels. Acetaldehyde and ethanol emissions showed a statistically significant increase of 31% and 77%, respectively, for E15 compared to E10. As expected, acetaldehyde and ethanol emissions were consistently higher for E15 compared to E10 as acetaldehyde emissions are a function of ethanol content.[34]

ii. Climate-Relevant Air Emissions

CO_2 emissions results from the Exhaust Emissions Study showed a marginally statistically significant reduction of 0.3% for E15 compared to E10 over the hot-start phase. No statistically significant differences in CO_2 emissions were seen for the weighted FTP test

[34] Karavalakis, G., Durbin T.D., & Tang, T. *Comparison of Exhaust Emissions Between E10 CaRFG and Splash Blended E15*. June 2022. https://ww2.arb.ca.gov/sites/default/files/2022-07/E15_Final_Report_7-14-22_0.pdf. Page 44.

cycle.[35] In general, an increase in CO_2 emissions does not necessarily suggest that the fuels lead to an overall increase in carbon emissions.

iii. Secondary Pollutants

Secondary pollutants form in the atmosphere through chemical and photochemical reactions from other primary pollutants. An example includes ozone, which is formed when hydrocarbons and NOx combine in the presence of light. Unlike many of the other GHGs, ozone is a short-lived gas that is found in regionally varying concentrations.

Both THC and NOx emissions determine ozone concentrations. As previously stated, THC emissions showed statistically significant reductions. NOx did not show any statistically significant difference between E15 and E10.

B. Conclusions

Based on the relative comparison between E15 fuel ethanol and E10 California reformulated gasoline, staff concludes that with fuel specifications and requirements, E15, as specified in the multimedia evaluation, does not pose a significant adverse impact on public health or the environment from potential air quality impacts. Staff also makes the following general conclusions:

- E15 reduces PM, THC and CO exhaust emissions.
- No statistically significant difference in NOx emissions compared to E10.
- E15 increases acetaldehyde and ethanol exhaust emissions. (CARB)

C. Recommendations

Based on the air quality assessment and evaluation of emissions impacts from the use of E15, CARB staff recommends that the CEPC find that the use of E15, as specified in the multimedia evaluation, does not pose a significant adverse impact on public health or the environment from potential air quality impacts, relative to E10 gasoline.

5. REFERENCES

Note: References are listed according to the corresponding footnote in the report. For references available online, electronic links have been provided. References used more than once are indicated as duplicate (e.g., "Same as Footnote 2"), excluding specific page numbers, and are listed to maintain the order and numbering of the footnotes in the report.

[35] Karavalakis, G., Durbin T.D., & Tang, T. *Comparison of Exhaust Emissions Between E10 CaRFG and Splash Blended E15.* June 2022. https://ww2.arb.ca.gov/sites/default/files/2022-07/E15_Final_Report_7-14-22_0.pdf. Page 54.

1. California Air Pollution Control Laws. Health and Safety Code, Division 26, Part 5, Chapter 4, Section 43830.8(b). *https://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?sectionNum=43830.8.&lawCode=HSC*.
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3. Automotive Testing and Development Services, Inc. *Comparison of Evaporative Emissions Between E10 CaRFG and Splash Blended E15*. January 2022.
4. California Air Resources Board. California Reformulated Gasoline Regulations. Title 13, California Code of Regulations, Sections 2250-2273.5. *https://ww2.arb.ca.gov/resources/documents/california-reformulated-gasoline-regulations*.
5. ASTM International. *ASTM D4806. Standard Specification for Denatured Fuel Ethanol Blending with Gasoline for Use as an Automotive Spark-Ignition Engine Fuel*. Oct 19, 2021.
6. California Code of Regulations. Title 13, Section 2260(a)(6.5). *https://ww2.arb.ca.gov/sites/default/files/2020-05/California_Reformulated_Gasoline_Regulations_2-16-14.pdf*.
7. University of California, Berkeley; University of California, Davis. *Guidance on the Types of Scientific Information to be Submitted by Applicants for California Fuels Environmental Multimedia Evaluations*. March 2016. Page 16. *https://ww2.arb.ca.gov/resources/documents/fuels-multimedia-evaluation-guidance-document*.
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10. Renewable Fuels Association, Growth Energy. *California Multimedia Evaluation of E11-E15 Gasoline-Ethanol Blends: Tier III Report*. March 8, 2024.
11. Same as Footnote 3.
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13. U.S. Environmental Protection Agency. *Final Rule: Regulation to Mitigate the Misfueling of Vehicles and Engines with Gasoline Containing Greater than Ten Volume Percent Ethanol.* https://www.epa.gov/gasoline-standards/final-rule-regulation-mitigate-misfueling-vehicles-and-engines-gasoline. Accessed Dec 24, 2024.

14. Same as Footnote 2.

15. Same as Footnote 2.

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23. Same as Footnote 2.

24. Same as Footnote 2.

25. Same as Footnote 2.

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27. California Air Resources Board. *Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Public Hearing to Consider Adoption of Regulations to Control Greenhouse Gas Emissions from Motor Vehicles.* August 6, 2004. Page i. https://ww2.arb.ca.gov/sites/default/files/barcu/regact/grnhsgas/isor.pdf.

28. United States Environmental Protection Agency. *Overview of Greenhouse Gases* website. *https://www.epa.gov/ghgemissions/overview-greenhouse-gases*. Accessed November 20, 2024.

29. California Air Resources Board. *Proposed Re-Adoption of the Low Carbon Fuel Standard. Staff Report: Initial Statement of Reasons.* December 2014, ES-2. *https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2015/lcfs2015/lcfs15isor.pdf*.

30. Same as Footnote 2.

31. Same as Footnote 3.

32. Same as Footnote 3.

33. Same as Footnote 3.

34. Same as Footnote 2.

35. Same as Footnote 2.

Below are the comments on the California E15 Multimedia Evaluation Tier I, II, and III Reports.

Background
State Water Resources Control Board (State Water Board) staff have completed the evaluation of potential surface water and groundwater impacts from E15 fuel. Staff based the assessment on the information provided in the multimedia evaluation reports (Final Tier I and Tier III Reports). The multimedia evaluation and State Water Board assessment of environmental impacts is specific to the difference between E15 and E10. E15 is an alternative fuel consisting of 15 percent ethanol and 85 percent gasoline.

Water Impacts
Based on a relative comparison between E10 and E15 fuel blends, State Water Board staff conclude:

- Increased use of ethanol in fuel will likely lead to a proportional increase in the quantity of ethanol released to the environment, with a roughly equivalent decline in the amount of petroleum released. Ethanol is readily biodegraded.
- Effects of ethanol on water quality and different aquatic species have been extensively studied. Sensitive crustaceans can be affected when exposed to 0.5 ppm ethanol for 72 hours, while most crustaceans exposed to ethanol concentrations of 1 part per thousand for 24 hours will result in injury.
- Off-normal release scenarios for E15 are the same as those of baseline fuel E10, as E15 would presumably be blended, stored, distributed, transported, handled, dispensed, and used by the same people and processes currently managing E10.
- Risk of human exposure posed by normal releases is generally limited to fuel vapor inhalation. Vapor concentrations in and around areas subject to normal releases of E15 are expected to be similar to those of E10.

Underground Storage Tank Material Compatibility and Leak Detection
California statutes and regulations require underground storage tank systems to be compatible with the substance stored, and the leak detection equipment to be able to function appropriately with the substance stored. Incompatibility increases the risk of unauthorized releases. Compatibility is verified by the local permitting agency with the underground storage tank owners and operators.

Underground storage tank regulations require the storage of substances not certified as compatible by an independent testing organization, typically Underwriters Laboratories (UL), if the manufacturer of the components provides affirmative statements of compatibility. Fiberglass underground storage tanks manufactured before April 1, 1990 (Xerxes) and July 1, 1990 (Owens Corning) cannot be certified by UL and both manufacturers will only certify compatibility with fuel blends containing a maximum of 10 percent ethanol or methanol.

Approximately 15 percent of California's existing secondarily contained underground storage tank infrastructure is not compatible with E15. State Water Board staff have identified approximately 5,100 non-compatible underground storage tanks in the State and an additional (estimated) 2,000 piping systems. Additionally, underground storage tank system upgrades require local agency permitting and review, and additional property improvements associated with local planning and fire code.

Distribution and Blending Equipment

Ethanol blends of E10 or E15 are not currently shipped by pipeline, nor are they expected to be shipped by pipeline in the future. Typically, gasoline and denatured ethanol are transported to a terminal where they are blended to appropriate concentration levels and shipped by tanker truck to individual retail stations.

Conclusions and Recommendations

Although a substantial portion of existing underground storage tank infrastructure would need to be upgraded, State Water Board staff concludes that given the similarities of E15 to E10, there are minimal additional risks to beneficial uses of California waters posed by E15 fuel blends than those posed by E10 fuel blends. The State Water Board supports the multimedia evaluation of E15 fuel blends and a finding of no significant impacts on public health or the environment.

Office of Environmental Health Hazard Assessment: The Potential for Toxicity of E15 versus E10 Exhausts

As part of the MultiMedia Working Group (MMWG), OEHHA reviewed Tier I, II, and III Reports on E15 and provided comments to CARB. OEHHA's assessment in this appendix is based on the information contained within the Tier Reports and focuses on the comparison of toxicity between E15 and E10 fuels.

OEHHA's Previous Assessment on the Health Risks of Ethanol in Gasoline

OEHHA previously assessed the potential health risks of ethanol in fuel, as an alternative oxygenate to methyl tertiary-butyl ether (MTBE).[1] In general, the addition of ethanol to fuel did not present significant risks to public health. The health risks associated with fuel stemmed primarily from the hydrocarbon portion of the fuel, including benzene, toluene, ethylbenzene, and xylenes (BTEX), its combustion byproducts (e.g., acetaldehyde, formaldehyde, and 1,3-butadiene), and secondary transformation products that may form in the atmosphere. These compounds remain a concern with E15 fuels; although, the increase in the percent volume of ethanol from 10% to 15% leads to a percent volume decrease of some of the other constituents of the fuel.

Findings on Comparative Toxicity from the Tier I Report

The Tier I Report included the results of a literature review of studies comparing the toxicity of ethanol blended fuels, including gasoline without ethanol (E0) and blends up to E85. Section 7, titled "Scientific Discussion of Human /Ecological Risk," summarized literature through early 2018. While none of the studies summarized in the report compared E15 and E10 fuels directly, the inclusion of a wide range of ethanol concentrations in the studies as a whole allowed for quantitative comparisons that enabled the estimation of the toxicity of any blend. The report indicated the following regarding the comparative toxicity of E15 versus E10.

- **Subacute, prenatal exposures to ethanol-gasoline blends suggest E15 will not be more toxic than E10 in relation to maternal, behavioral, immunological, physiological, or cognitive outcomes.** In a study of pregnant rats exposed for 12 consecutive days to inhaled E0 or E85 at concentrations 4–6 orders of magnitude higher than typical public exposures and more than 10 times higher than occupational exposure limits, there were no signs of overt maternal toxicity and no consistently altered behavioral, immunological, or physiological response patterns in the offspring.[2] A follow-up study of adult offspring exposed

[1] OEHHA (1999). *Potential Health Risks of Ethanol in Gasoline*. Office of Environmental Health Hazard Assessment (OEHHA). Last accessed January 2025, at https://oehha.ca.gov/air/crnr/potential-health-risks-ethanol-gasoline

[2] Bushnell PJ, Beasley TE, Evansky PA, Martin SA, McDaniel KL, Moser VC, and Rogers JM (2015). Toxicological assessments of rats exposed prenatally to inhaled vapors of gasoline and gasoline-ethanol blends. *Neurotoxicol Teratol*, 49, 19–30. DOI: 10.1016/j.ntt.2015.02.004.

prenatally to E0, E15, or E85 showed that the few cognitive effects observed relative to air-exposed controls could not be attributed to the ethanol concentration in the fuel blend and were likely due to a combination of hydrocarbons.[3] Cumulatively, the lack of consistent differences in offspring assessed for numerous health endpoints at various stages of development (pre-weaning to adulthood) provided evidence that E15 may not be more toxic than E10.[4]

- **Subchronic inhalation exposures to gasoline (E0) or gasoline combined with fuel oxygenates (e.g., ethanol) suggest that evaporative emissions from E15 might not produce an increased health hazard compared to E10. However, more comprehensive evaluations are needed.** Evaporative emissions occur through various pathways, including refueling activities (e.g., spills and direct vehicle emissions) and diurnal/breathing and running losses. These emissions apply to occupational and public exposures (e.g., at retail service stations or during accidental spill events). Adult rats exposed for 13-weeks to E0 or ethanol blended gasoline at concentrations several orders of magnitude higher than typical public exposures had the same no observed adverse effect level (NOAEL) for numerous health outcomes, including but not limited to body and organ weights, blood parameters, and effects on the central nervous system (CNS) and motor activity.[5] The concentration of ethanol in the blended gasoline was not specified but possibly 13.3% based on information from a related method paper.[6] The lack of a difference between E0 and the ethanol blended gasoline provided evidence that the use of E15 would be unlikely to increase the hazards of evaporative emissions from refueling relative to E10. Separate experiments conducted under the same conditions as the 13-week study revealed that the ethanol blended gasoline produced signs of gliosis, a CNS response to tissue injury, but the severity of the effect was barely above baseline and did not approach the level known for neurotoxicants that produce only subtle damage to the affected brain area.

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[3] Oshiro WM, Beasley TE, McDaniel KL, Evansky PA, Martin SA, Moser VC, Gilbert ME, and Bushnell PJ (2015). Prenatal exposure to vapors of gasoline-ethanol blends causes few cognitive deficits in adult rats. *Neurotoxicol Teratol*, 49, 59–73. DOI: 10.1016/j.ntt.2015.04.001.

[4] OEHHA found a separate study (Herr et al. 2016) that was not included in the Tier I Report but tested the neurotoxicological effects of a subacute inhalation exposure paradigm like that of Bushnell et al. (2015) and Oshiro et al. (2015). The results of Herr et al. (2016) generally agreed with the lack of consistent differences due to ethanol concentration and showed no biologically significant changes in adult offspring exposed prenatally to E0, E15, or E85 vapors. [Reference: Herr DW, Freeborn DL, Degn L, Martin SA, Ortenzio J, Pantlin L, Hamm CW, and Boyes WK (2016). Neurophysiological assessment of auditory, peripheral nerve, somatosensory, and visual system function after developmental exposure to gasoline, E15, and E85 vapors. *Neurotoxicol Teratol*, 54, 78–88. DOI: 10.1016/j.ntt.2015.12.006.]

[5] Clark CR, Schreiner CA, Parker CM, Gray TM, and Hoffman GM (2014). Health assessment of gasoline and fuel oxygenate vapors: Subchronic inhalation toxicity. *Regul Toxicol Pharmacol*, 70, S18–S28. DOI: 10.1016/j.yrtph.2014.07.003.

[6] Henley M, Letinski DJ, Carr J, Caro ML, Daughtrey W, and White R (2014). Health assessment of gasoline and fuel oxygenate vapors: generation and characterization of test materials. *Regul Toxicol Pharmacol*, 70 (2 Suppl):S13–7. DOI: 10.1016/j.yrtph.2014.05.012.

OEHHA: The Potential for Toxicity of E15 versus E10 Exhausts

- **Experiments on human cells suggest that E15 will not be more potent than E10 in terms of its cytotoxic, pro-inflammatory, oxidative stress, mutagenic, or DNA-damage effects.**
    - A multi-cellular human lung model exposed to exhaust from a passenger car fueled with E0, E10, or E85 for six hours did not induce adverse cell responses. No cytotoxicity, morphological changes, oxidative stress, deoxyribonucleic acid (DNA) damage, or induction of genes related to oxidative stress or pro-inflammation processes was observed,[7] providing evidence that the use of E15 will not result in increased observed toxicity compared to E10.
    - Human lung cells and white blood cells exposed for two or six hours to E0 or E85 showed less oxidative DNA damage with E85 exposure.[8]
    - Human lung cells exposed to exhaust particulate matter (PM) from a car fueled with E0 or E15 did not show significantly different effects in relation to DNA damage, oxidative stress, polycyclic aromatic hydrocarbon (PAH) metabolism, or pro-inflammatory responses.[9] These findings provided further evidence that increased toxicity will not be observed with the use of E15 versus E10.
    - In additional studies published after the literature review for the Tier I Report and identified by OEHHA, human lung cells exposed to PM from a vehicle operated with different ethanol-gasoline blends had variable responses depending upon the ethanol concentration in the fuel.
        - Comparisons of eight fuels with varying ethanol concentrations and total aromatic content (TAC) showed that PM emissions from fuels with higher ethanol concentrations downregulated interleukin (IL)-6, a pro-inflammatory cytokine that affects immune, inflammation, and other physiological processes, less than fuels with lower ethanol concentrations but the same/similar TAC.[10] Ethanol concentrations were 0%, or approximately 10%, 15%, or 20% by volume, and TAC was approximately 20% or 30% by volume, making this the only study reviewed by OEHHA to

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[7] Bisig C, Roth M, Müller L, Comte P, Heeb N, Mayer A, and Rothen-Rutishauser B (2016). Hazard identification of exhausts from gasoline-ethanol fuel blends using a multi-cellular human lung model. *Environ Res*, 151, 789–796. DOI: 10.1016/j.envres.2016.09.010.

[8] Roth M, Usemann J, Bisig C, Comte P, Czerwinski J, Mayer A, Beier K, Rothen-Rutishauser B, Latzin P, and Müller L (2017). Effects of gasoline and ethanol-gasoline exhaust exposure on human bronchial epithelial and natural killer cells in vitro. *Toxicol in Vitro*, 45, 101–110. DOI: 10.1016/j.tiv.2017.08.016

[9] Libalova H, Rossner P Jr, Vrbova K, Brzicova T, Sikorova J, Vojtisek-Lom M, Beranek V, Klema J, Ciganek M, Neca J, Machala M, and Topinka J (2018). Transcriptional response to organic compounds from diverse gasoline and biogasoline fuel emissions in human lung cells. *Toxicol in Vitro*, 48, 329–341. DOI: 10.1016/j.tiv.2018.02002.

[10] Sabbir Ahmed CM, Yang J, Chen JY, Jiang H, Cullen C, Karavalakis G, and Lin Y-H (2020). Toxicological responses in human airway epithelial cells (BEAS-2B) exposed to particulate matter emissions from gasoline fuels with varying aromatic and ethanol levels. *Sci Total Environ*, 706: 135732. DOI: 10.1016/j.scitotenv.2019.135732.

have compared E10 and E15 fuels.[11] Based on previous research, the authors hypothesized that the higher ethanol concentrations reduced the concentrations of PAH species in the PM. Because PAHs can suppress IL-6 expression, the fuels with higher ethanol concentrations were thought to neutralize the immunosuppressive effects of the PAHs in comparison to the fuels with lower ethanol content. Cytotoxicity tests revealed that none of the tested fuels induced cytotoxicity more than 30% relative to unexposed (negative control) cells, and the comparisons between E10 and E15 fuels with the same TAC did not show consistent results.[12]

- Organic extracts from PM generated by an E0- or E15-fueled spark-ignited engine produced differing health effects, with the E15 extract exhibiting higher toxic potency due to a higher PAH content compared to the E0 extract.[13] After 24-hour exposures, human lung cells exposed to the E15 versus E0 extract had more dysregulated genes and pathways related to cancer promotion and progression. While the study authors stated that an ethanol additive may affect the chemical composition and increase the toxic potency of exhaust PM, they also discussed the limitations of the study and the need to explore the impacts of complete gasoline emissions, including but not limited to gaseous components (e.g., nitrogen oxides or NO_x) and carcinogenic byproducts (e.g., formaldehyde) of ethanol-blended fuel combustion.
- In a study of PM extracts generated by a direct-injection engine but similar to the study mentioned in the previous bullet, the organic E15 PM extract exhibited lower genotoxic potency and produced less oxidative DNA

[11] The ethanol content (vol%) and total aromatic content (TAC; vol%) of the fuels tested by Sabbir-Ahmed et al. (2020) were reported in a separate study (reference in brackets). Fuel 1 (E0, TAC 20); Fuel 2 (E0, TAC 30); Fuel 3 (E10, TAC 20); Fuel 4 (E10, TAC 30); Fuel 5 (E15, TAC 20); Fuel 6 (E15, TAC 20); Fuel 7 (E15, TAC 30); and Fuel 8 (E20, TAC 19). Fuels 5 and 8 were created by diluting Fuel 3 with a specified volume of ethanol, a process also called "splash blending." The other five fuels were match blended, a process in which the blendstock composition is adjusted for each ethanol-gasoline blend to match one or more fuel properties, such as aromatic and ethanol content. Fuels 5 and 6 had similar aromatic and ethanol levels and were included to determine the effects of the different blending practices. The fuels were also blended to represent lower and higher PM indices (PMIs), with the low PMI values (for Fuels 1, 3, 5, 6, and 8) ranging from 1.613–1.888 and the high PMI values (for Fuels 2, 4, and 7) ranging from 2.039–2.330. A PMI is a modeled value that quantifies the relationship between gasoline properties and PM emissions based on fuel composition; it estimates a fuel's tendency to produce PM emissions, with higher PMI values indicating a fuel has a higher potential to generate PM emissions. [Yang J, Roth P, Zhu H, Durbin TD, and Karavalakis G (2019). 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. DOI: 10.1016/j.fuel.2019.04.144.]

[12] Comparisons of the fuels with the same or similar TAC but different ethanol concentrations showed inconsistent results. Fuels 5 and 6 (E15, TAC 20) had ~30% cytotoxicity, while Fuel 3 (E10, TAC 20) showed no cytotoxicity and Fuel 8 (E20, TAC 19) only caused ~5% cytotoxicity. A comparison of the TAC 30 fuels found little difference in cytotoxicity between Fuel 7 (E15, TAC 30) and Fuel 4 (E10, TAC 30).

[13] Líbalová H, Závodná T, Vrbová K, Sikorová J, Vojtíšek-Lom M, Beránek V, Pechout M, Kléma J, Ciganek M, Machala M, Neča J, Rössner P Jr, and Topinka J (2021). Transcription profiles in BEAS-2B cells exposed to organic extracts from particulate emissions produced by a port-fuel injection vehicle, fueled with conventional fossil gasoline and gasoline-ethanol blend. *Mutat Res Genet Toxicol Environ Mutagen*, 872:503414. DOI: 10.1016/j.mrgentox.2021.503414.

damage than the E0 extract.[14] The authors related the difference to the higher amount of nitro-PAHs and especially 1-nitropyrene, a carcinogenic PAH, in the E0 extract compared to the E15 one.

- PM emitted from a vehicle operated using a United States Environmental Protection Agency (US EPA) Tier III E10,[15] an E10 with higher aromatic levels than the Tier III E10, an E30, and an E78 blend produced variable oxidative potential and inflammatory activity when the blends were compared by ethanol content and the results were presented as emission factors or intrinsic PM potential (i.e., normalized per mile or per milligram of PM mass, respectively).[16] Oxidative potential was measured as macrophage reactive oxygen species production and dithiothreitol consumption, while inflammatory activity was measured as tumor necrosis factor alpha (TNFα)[17] excretion. Each fuel was tested six times, over triplicate cold- and hot-start test cycles. No bacterial mutagenicity was observed for any of the samples tested. It was unclear to OEHHA whether the health endpoints were compared statistically. However, the E78 fuel appeared to have the least oxidative potential for the mile- and mass-normalized data. Tier III E10 reportedly had the greatest oxidative potential and inflammatory activity for the mile-normalized data, but the agreement between tests on both the “per mile” and “per mg” normalizations of the oxidative potential values was poor for this fuel type. When the tests were averaged for each fuel type, E30 and E78 were said to have the greatest intrinsic oxidative potential and intrinsic inflammatory activity, respectively. Overall, the trends in the data normalized by mile were said to be primarily influenced by differences in the PM mass emission rates and only secondarily by the intrinsic toxicity of the PM. OEHHA notes that the study did not assess or discuss how other physicochemical characteristics (e.g., differences in the emitted particle numbers, surface area, size distribution, or acetaldehyde content) might have affected the toxicity of the various fuels.

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[14] Líbalová H, Závodná T, Elzeinova F, Barosova H, Cervena T, Milcova A, Vankova J, Paradeisi F, Vojtíšek-Lom M, Sikorova J, Topinka J, and Rössner P (2023). The Genotoxicity of organic extracts from particulate emissions produced by neat gasoline (E0) and a gasoline-ethanol blend (E15) in BEAS-2B cells. *J Xenobiot*, 14(1):1–14. DOI: 10.3390/jox14010001.
[15] Tier III gasoline follows standards set by the US EPA (2014). It is an E10 blend, containing 10% ethanol and 90% gasoline, with a low sulfur content averaging approximately 10 parts per million (ppm) per year. Tier III E10 is the standard fuel type used to test emissions from newer vehicles certified under Tier III emissions regulations.
[16] Yang J, Roth P, Durbin TD, Shafer MM, Hemming J, Antkiewicz DS, Asa-Awuku A, and Karavalakis G (2019). Emissions from a flex fuel GDI vehicle operating on ethanol fuels show marked contrasts in chemical, physical and toxicological characteristics as a function of ethanol content. *Sci Total Environ*, 683: 749–761. DOI: 10.1016/j.scitotenv.2019.05.279.
[17] TNFα is a pro-inflammatory chemical messenger that can trigger systemic inflammation and cell death when elevated.

OEHHA: The Potential for Toxicity of E15 versus E10 Exhausts

- **The toxicological risk to ecological receptors is similar between E15 and E10, as E15 has a similar potential for environmental releases affecting land, groundwater, surface water, and air.** Microbial activity plays a large role in the biodegradation of released chemicals; however, while ethanol inhibits microbial activity, its rapid volatilization and degradation in the environment makes it unlikely that E15 is more toxic to environmental microbes compared to E10. Many aquatic organisms are sensitive to changes in aqueous ethanol concentrations, but the hydrocarbon components of the fuel are relatively more toxic. As stated in the Tier I Report, "While unique considerations relative to ethanol releases to surface water bodies exist for ecological receptors (See Section 6.5), risks due to E15 use vs. E10 are not materially different." Addition details on ecological toxicity and risk can be found in the Tier I Report.

Summary of Findings on Comparative Toxicity from Tier I Report

The Tier I Report concludes that the use of ethanol-gasoline blends in the E11–E15 range would not result in any release scenarios or human or environmental impacts different from those that already occur with existing fuels.

The Tier I Report also states the following:

"As with E10, E15 would have the potential to be released into the environment affecting land, groundwater, surface water, and from there into drinking water supplies, and allowing receptors to be exposed via ingestion, dermal exposure and inhalation. Such releases have the potential to impact drinking water supplies such as surface water and groundwater. E15 provides potential for inhalation exposures to exhaust and evaporative emissions, and to soil vapors entering indoor air. Other human and ecological risks associated with E15 blends would not be significantly different than those present from the widespread use of E10."

The additional toxicological/mechanistic studies published since the Tier I Report and summarized above do not change the conclusion from the Tier I Report regarding the public health impact of E15 compared to E10.

Findings on Comparative Exposure from the Tiers I and II Reports

E15 has a similar potential for human exposure as E10. Exposures can occur from both normal use of E15 and from environmental releases, such as spills. Potential routes of exposure include inhalation, dermal contact, and oral ingestion. Inhalation exposure is the most likely route of exposure and can result from tailpipe and evaporative emissions from vehicles using E15, volatile compound evaporation during fuel handling, and vapors could migrate from contaminated soil and soil vapor into the indoor air. Dermal exposure can occur while handling fuel or contacting contaminated soil. Oral exposures can occur through contamination of drinking water supplies.

OEHHA: The Potential for Toxicity of E15 versus E10 Exhausts

The increased ethanol content in E15 results in a proportional decrease in the hydrocarbon portion of the fuel, resulting in a slight decrease in exposure to toxic volatile organic compounds (VOCs), such as benzene. For example, the percent volumes of benzene in E15 and E10 are expected to be 1.04 and 1.10, respectively.[18]

Tailpipe emissions are likely to be the main source of inhalation exposure. Testing showed a general decrease in most tailpipe emissions, including carbon monoxide (CO), total hydrocarbons (THC), non-methane hydrocarbons (NMHC), PM (mass), and some VOCs. Of the over 70 chemicals measured, there were few differences between E15 and E10 fuels, including significant or marginally significant decreases in ethylbenzene, m/p-xylenes, and o-xylenes (by 11%, 10%, and 9%, respectively) in the E15 tailpipe emissions.[19] There were no significant differences between E15 and E10 fuels for the toxic air contaminants 1,3-butadiene, benzene, formaldehyde, and toluene. Increased ethanol and acetaldehyde emissions (77% and 32%, respectively) were also measured. However, human exposure to acetaldehyde will not necessarily increase by the same proportion, especially considering its multiple sources (i.e. direct emissions and formation through atmospheric oxidation reactions). Without additional information, OEHHA is unable to assess the change in risk to humans and the environment. Figure 29 in the Tier I Report shows cancer risk due to air toxics including benzene, 1,3-butadiene, formaldehyde, and acetaldehyde in California, and demonstrates that the increase in acetaldehyde concentrations due to increased ethanol use did not result in increased risk as ethanol was phased in after 1999. The calculations took into account early-in-life sensitivity to carcinogens. The increased ethanol concentrations are expected to have no impact on health, due to ethanol's low anticipated health risk relative to other fuel-related chemicals of concern, and low amount expected to be inhaled given the likely outdoor exposure. Inhalation exposure resulting from the evaporation of volatile compounds can occur with vehicle refueling, fuel spills, and fuel transport. Evaporative emissions resulting from the volatilization of compounds from within the fuel system are not expected to differ since E15 and E10 have similar vapor pressures, as described in the Tier I Report. Evaporative emissions testing, detailed in the Tier II Report, found no statistically significant difference between E15 and E10. Exposure can also occur with vapor intrusion from contaminated soil and soil vapor that migrates through the soil into the indoor air of a building. According to the Tier I Report, the benzene component of E11–15 ethanol-gasoline blends is the primary risk driver for long-term vapor intrusion.[20] However, the applicability of currently accepted vapor intrusion vertical screening distances to E15 releases is unknown and requires validation, as the distances are based on risk data from E0–E10 fuels.

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[18] Tier I Report, Table 13
[19] Tier III Report, page 6
[20] While the Tier I Report did not specify the duration of "long-term," it may be on the order of years, depending upon the environmental conditions and the amount of fuel spilled. The Report explains that with ethanol-blended fuels, there is documented potential preferential degradation of ethanol over BTEX constituents, causing them to persist in the environment longer than predicted.

OEHHA: The Potential for Toxicity of E15 versus E10 Exhausts

Ethanol may enhance the skin penetration and absorption of other chemicals, but oral and dermal exposures are unlikely to differ significantly between E15 and E10. While there is an increase in ethanol content, it is highly volatile and unlikely to contribute additional risk via these exposure routes. The risks associated with exposures to the other constituents of the E15 fuel do not change appreciably and remain similar to the risk associated with E10.

Key Findings and Conclusions

- **Comparison of Key Chemicals of Concern:** The key chemicals of concern are the same for E15 and E10. These chemicals include ethanol, BTEX, acetaldehyde, formaldehyde, 1,3-butadiene, acrolein, and naphthalene, as shown in Table 19 of the Tier I Report.

- **Comparative Toxicity:** Based on studies in experimental animals, subacute exposure to E15 does not appear to be more toxic than E10 in relation to maternal, behavioral, immunological, physiological, or cognitive outcomes. Subchronic inhalation exposure to evaporative emissions of ethanol-gasoline blends may not increase health hazard, but additional evaluations are warranted. *In vitro* experiments in human cell lines suggest E15 is not more potent than E10 in inducing oxidative stress or cytotoxic, pro-inflammatory, mutagenic, or DNA-damage effects.

- **Comparison of Exposure Scenarios and Environmental Fate:** Exposure scenarios for E15 are expected to be similar to those for E10 and include inhalation, oral, and dermal routes. E15 significantly reduces tailpipe emissions of PM, CO, THC, NMHC, and some VOCs compared to E10, without increasing NO_x or carbon dioxide emissions. There are no statistically significant differences for the toxic air contaminants 1,3-butadiene, benzene, formaldehyde, and toluene. However, increases in ethanol and acetaldehyde emissions were measured. In release scenarios, increased ethanol use could lower the overall toxicity of fuel spills by reducing petroleum-derived BTEX compounds, and ethanol itself biodegrades quickly in the environment.

- **Public Health Impacts:** OEHHA did not find evidence of significant adverse impacts on human public health from the use of E15 compared to E10. However, there is some uncertainty and/or a data gap that precludes OEHHA from conclusively determining a lack of an impact. For example, inhalation studies in animals that directly compare the toxicity of E15 and E10 would be informative. The Tier Reports support the approval of E15, based on significant environmental benefits, reduced greenhouse gas emissions, and no expected significant new public health risks compared to E10.

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Gavin Newsom
Governor

M E M O R A N D U M

DATE: November 7, 2025

TO: Multimedia Working Group
California Environmental Policy Council

FROM: Mohammed Omer, P.E.
Unit Chief
Permitting Division
Hazardous Waste Management Program
Department of Toxic Substances Control

SUBJECT: DTSC's Recommendation on E15 Multimedia Evaluation

A multimedia evaluation of E15 must be conducted and reviewed by the California Environmental Policy Council (CEPC). A Multimedia Working Group (MMWG), of which DTSC is a member, has been established to make recommendations to the CEPC regarding the acceptability of new fuel formulations, such as E15, proposed for use in the State.

E15 is a gasoline fuel blend of 15 percent ethanol and 85 percent gasoline; currently, substantially all fuel sold in California is referred to as E10. The E15 Multimedia Evaluation Tier I, II, and III Reports were developed to study E15 and its potential impacts to the environment. Tier I studied the chemistry of E15 and potential release scenarios and environmental behavior of E15 and identified knowledge gaps. Tier II was a study of the impact of higher ethanol content on tailpipe and evaporative emissions. Finally, Tier III summarized and synthesized the previous Tier I and II reports and made recommendations to the MMWG, regarding the suitability of E15 for fuel use in California.

DTSC staff evaluated impacts of E15 to human health and the environment during its manufacture, storage, transport, and use in California. Specifically, DTSC's evaluation focused on (1) hazardous waste generation during production, use, and storage of E15 in California and (2) cleanup of contaminated sites in cases of spills of E15. Based on the staff evaluation, the following points were noted:

1. Production of the increased ethanol to make E15 is centered around the fermentation of organic feedstocks.
2. This fermentation process does not generate hazardous waste byproducts.
3. Existing regulations, primarily for storage tanks, in federal and State law, are likely sufficient to continue to protect human health and the environment.
4. Pollutants found in gasoline-ethanol blends (benzene, toluene, ethylbenzene, and xylene, collectively known as BTEX) would be reduced as the ethanol concentration increases.
5. Conversely, in the event of an inadvertent release, BTEX would degrade more slowly in the environment, with statistically longer benzene plumes, as ethanol concentration increases, compared with E10.
6. Methane production would increase in soil and water (surface and groundwater) in the event of an inadvertent release of E15, as compared with E10.
7. The primary human carcinogen found in fuel blends, benzene, is expected to decrease as ethanol concentration increases.
8. Overall, the human and ecological risks associated with E15 are largely similar to those associated with E10.

As more ethanol is produced, and newer technologies for its production are developed, point 2 above may need to be readdressed through appropriate evaluation, ideally through the MMWG process.

<u>DTSC Conclusions and Recommendations</u>

DTSC supports the E15 multimedia evaluation based on the reduction of greenhouse gas emissions, and under the following conditions.

1) If any potential future technologies dedicated to ethanol production lead to the generation of hazardous substances and/or hazardous wastes, including additives to E15, that the MMWG process be followed for an appropriate environmental impact evaluation; and

2) Ethanol and ethanol-blended fuels must continue to be handled in compliance with applicable State and federal regulations.

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