California Air Resources Board

Proposed Re-Adoption of the Low Carbon Fuel Standard

Comments Submitted by the Energy Future Coalition and the Urban Air Initiative

February 17, 2015

The Energy Future Coalition and Urban Air Initiative commend CARB for its groundbreaking work in the area of low carbon transportation fuels, and we appreciate this opportunity to comment on ways to further improve on the efficacy of California’s Low Carbon Fuel Standard (LCFS). CARB has the opportunity with this rulemaking, in reducing the carbon footprint of the California transportation sector, to take steps that will not only help address the threat of global climate change, but also mitigate serious impacts on public health.

As summarized here and developed more fully in the appendices, these comments argue that:

1. Automakers who continue to use internal combustion engines must increase engine efficiency to meet LCFS standards and reduce GHGs.
2. Displacing aromatics now used for octane in gasoline would produce substantial benefits for public health.
3. Increased use of domestically produced renewable ethanol is essential to both objectives and would have additional co-benefits.
4. The LCFS should fully reflect the latest research on the value of mid-level ethanol blends to reduce GHGs and benefit public health and the environment through the displacement of aromatics.

**About the Energy Future Coalition and the Urban Air Initiative**

The Energy Future Coalition is a broad-based, non-partisan public policy initiative, co-located with the United Nations Foundation in Washington, DC. The Coalition seeks to bridge the differences among stakeholder groups and identify domestic energy policy options that can find broad political support and accelerate the transition to a clean energy economy. Since the Coalition’s founding in 2002, one of its principal areas of interest has been the potential of clean renewable fuels to reduce the nation’s dependence on oil. This has led to a focus on the public health consequences of the use of aromatic compounds to enhance octane in gasoline. On two occasions, most recently last year, the Coalition co-hosted workshops on this topic with the National Institute of Environmental Health Sciences (NIEHS).

The Urban Air Initiative is a non-profit entity dedicated to research and education in the area of fuel quality and its relationship to mobile source emissions, especially in urban areas. The climate and public health impacts of mobile source (traffic) pollution—in the U.S. and globally—are of great importance to policymakers, industries, and the billions of people that are regularly exposed to harmful pollutants in their homes, schools, and vehicles. Among the most vulnerable are infants and children. The Urban Air Initiative believes that protecting our children’s health and well-being is the most important investment society can make to build a better future.

Toward that end, in recent years our two organizations have analyzed dozens if not hundreds of peer-reviewed studies supported and/or conducted by the U.S. Environmental Protection Agency (EPA), the Health Effects Institute (HEI), NIEHS, the U.S. Department of Energy (DOE), the National Oceanographic and Atmospheric Administration (NOAA), numerous federal laboratories (e.g., Argonne, Oak Ridge, NREL, Pacific Northwest, etc.), the California Air Resources Board (CARB), academic institutions, auto companies, and many others.

**Context of the LCFS Rulemaking**

For many years, California has been a global trend-setter in transportation fuels regulatory policy. The state is one of the world’s largest consumers of gasoline, and it has more gasoline-powered light duty vehicles (LDVs) than most nations. Consequently, CARB has led the way in addressing the serious health and climate threats from gasoline combustion by-products. By law, California has special status—relative to other states—in terms of establishing fuel quality standards under the Clean Air Act. CARB’s experts recognize that fuel composition is just as important as vehicle control technologies in reducing emissions of carbon and other harmful pollutants.

The December 2014 CARB staff report on the LCFS, “Initial Statement of Reasons for Proposed Rulemaking,” notes in the Executive Summary that “the production, transport, and use of traditional fuels are responsible for nearly half of the state’s greenhouse gas (GHG) emissions” and states: “The primary goal of the LCFS regulation is to reduce the carbon intensity of transportation fuels used in California by at least ten percent by 2020 from a 2010 baseline.” It goes on to say, “The LCFS is a key part of a comprehensive set of programs in California to reduce GHG emissions and other smog-forming and toxic air pollutants from the transportation sector.”

These comments are intended to show the link between reducing “GHG emissions and other smog-forming and toxic air pollutants from the transportation sector” and to “encourage the use of cleaner low-carbon fuels in California, encourage the production of those fuels, and, therefore, reduce GHG emissions.”

**Statement of the Case**

1. **Automakers who continue to use internal combustion engines must increase engine efficiency to meet LCFS standards and reduce greenhouse gas emissions.**

Meeting the California LCFS standards by 2020, the EPA’s ambitious fuel economy standards of 54.5 miles per gallon by 2025, and the “more aggressive targets for 2030” forecast for California in the current rulemaking will require a fleet-wide transition to light-duty vehicle technologies capable of much greater efficiency. While electric vehicles are gaining traction, they are not expected to achieve substantial market penetration in that time, nor are hydrogen fuel cell vehicles likely to be commercially viable at scale. Even in 2040, according to the U.S. Energy Information Administration, cars with gas- and diesel-powered engines will still represent some 95% of the international car market. Continued evolution of today’s internal combustion engines, on the other hand, can achieve the fuel economy targets at an affordable cost. Highly efficient high-compression engines offer the cheapest and most certain path to the GHG and fuel economy standards of the future. The limiting factor is not scalable vehicle technology, but fuel—specifically its octane rating.

The efficiency of an internal combustion engine increases as a factor of its compression ratio – which reflects the amount of fuel burned in a single piston stroke. Higher-octane fuels are needed to enable higher compression ratios – they can withstand a greater rise in temperature during the compression stroke without igniting, thus allowing more power to be extracted. (Uncontrolled combustion, or knock, is harmful to an engine and would render a vehicle unmarketable.)

Thus, to perform adequately, high-compression engines require higher-octane fuel than today’s regular-grade gasoline. Premium gasoline can deliver more octane at a higher cost but is currently produced by the addition of a blend of toxic aromatic hydrocarbons, implicated in a range of serious health effects. Clean-burning alcohol fuels such as ethanol, on the other hand, are inherently high in octane. These fuels – which, unlike gasoline, can be produced from a variety of feedstocks, including cellulosic biomass, municipal waste, and even natural gas – can enable greater fuel economy while providing substantial environmental benefits and dramatically reducing oil dependence in the next decade, at a price that mainstream Americans can afford.

Automakers have asked EPA for higher-octane gasoline to comply with the new fuel efficiency-carbon reduction rules.[[1]](#footnote-1) Higher-octane gasoline would enable a compression ratio increase of approximately 2 numbers, significantly increasing fuel efficiency while reducing the most harmful emissions. To do that, automakers need an octane pool of 94 AKI (100 RON) gasoline, as compared with today’s U.S. market standard of 87 AKI.

Ethanol has superior octane enhancement properties compared to other alternatives. Technically, economically, and legally (because the Clean Air Act limits the amount of aromatics in reformulated gasoline), the best and perhaps only way to make 94 AKI gasoline available nationwide is with mid-level ethanol blends (discussed here as E30). These blends have been shown in tests by automakers and Oak Ridge National Laboratory to have superior performance and emissions characteristics – mid-level ethanol blends have been called by Oak Ridge a “renewable super premium” fuel.

Recalling that the “primary goal of the LCFS regulation is to reduce the carbon intensity of transportation fuels used in California,” ethanol has the following significant carbon-reducing effects compared to gasoline:

1. Argonne National Laboratory has devoted 20 years of research and analysis to the life-cycle greenhouse gas impacts of transportation fuels. As a 2012 Argonne paper summarized, “advances in technology and the resulting improved productivity in corn and sugarcane farming and ethanol conversion … have increased the energy and greenhouse gas (GHG) beneﬁts of using bioethanol.” Compared to regular gasoline, it showed a “well-to-wheels” reduction in GHG emissions from corn-based ethanol of 44% and from cellulosic ethanol of 89-95%.[[2]](#footnote-2)

To be sure, as agricultural production increases to support ethanol production, concerns about land use and indirect GHG effects must also be considered. A widely circulated and globally influential paper by Timothy Searchinger concluded that those effects are so negative as to overwhelm ethanol’s GHG benefits. However, this paper has since been shown to be simplistic in its approach and wrong in its conclusion. Several peer-reviewed analyses have been published, most notably by Argonne, that show the indirect land use impacts hypothesized by Searchinger were overestimated by an order of magnitude. Including the recalculated indirect land use effects in the analysis cited above still results in a reduction of GHG emissions from corn-based ethanol of 34% and from cellulosic ethanol of 88-108% compared to gasoline.

1. That same Argonne research gives no credit for corn’s ability to fix carbon in soil permanently. Recent research is showing that modern, high-yield continuous corn grown using conservation or no-till practices is in fact sequestering and rebuilding the carbon content of soil in the Midwest. Argonne is beginning a new study of soil carbon fixation, as well as NOx emissions related to fertilizer use, with regard to its GHG estimates for corn ethanol. Current EPA and CARB life-cycle analysis models similarly underestimate corn’s superior ability as a highly efficient C4 plant in sequestering carbon, and should be updated accordingly.[[3]](#footnote-3)
2. Gasoline itself is increasing in carbon intensity as oil from energy-intensive operations, such as heavy crudes from the Alberta tar sands and North Dakota fracking operations in the Bakken field, come to market.
3. Aromatics require the most energy to produce in the already energy-intensive oil refining process. An E30 blend would reduce refinery CO2 emissions by 10%.[[4]](#footnote-4)
4. Because of their chemical structure, aromatics are among the most carbon-rich components of gasoline. A recent report by a Health Effects Institute panel noted that aromatics “represent one of the heaviest fractions in gasoline” and said: “The aromatic content of gasoline has a direct effect on tailpipe carbon dioxide emissions.  The EPEFE study[[5]](#footnote-5) demonstrated a linear relationship between CO2 emissions and aromatic content.  A reduction of aromatics from 50 to 20% was found to decrease CO2 emissions by 5%.”[[6]](#footnote-6)
5. **Displacing aromatics now used for octane in gasoline would produce substantial benefits for public health.**

Aromatic hydrocarbons have been known for a long time to be toxic in their own right. California has limited the amount of aromatics in diesel fuel since 1988, and the Clean Air Act Amendments of 1990 limited the permissible amount of aromatics in reformulated gasoline. Yet the BETX group of chemicals (i.e., benzene, ethylbenzene, toluene, and xylene) still comprises 25-30% of the average gallon of gas. Benzene is a proven human carcinogen that can cause leukemia in exposed persons, and the other aromatics (mainly toluene and xylene) are neurotoxins. Combustion of these aromatics can lead to the formation of benzene in the exhaust gas. According to the HEI report just cited, “It is estimated that about 50% of the benzene produced in the exhaust is the result of decomposition of aromatic hydrocarbons in the fuel.” The same report also noted, “Lower levels of aromatics enable a reduction in catalyst light-off time for all vehicles. Research indicates that combustion chamber deposits can form from the heavier hydrocarbon molecules found in the aromatic hydrocarbon portion of the gasoline. These deposits can increase tailpipe emissions, including carbon dioxide, hydrocarbons and NOx.”

Of even greater concern, aromatics’ emission products are transformed in the atmosphere into secondary organic aerosol (SOA). An important study from the Harvard Center for Risk Analysis, which focused specifically on the public health impacts of secondary particulate formation from aromatic hydrocarbons in gasoline, reported: “Evidence is growing that aromatics in gasoline exhaust are among the most efficient secondary organic matter precursors. … For example, a source apportionment study of SOA formation during a severe photochemical smog event in Los Angeles found that gasoline engines represented the single-largest anthropogenic source of SOA. … Source-specific speciation of total VOC in the 2005 National Emissions Inventory reveals that the U.S. emissions of single-ring aromatic hydrocarbons are 3.6 million tons per year, of which 69% are from gasoline-powered vehicles.”[[7]](#footnote-7) The Harvard study predicted 3,800 premature mortalities per year due to aromatics.

Among the toxic SOA emission products from partial combustion of the aromatics in gasoline are polycyclic aromatic hydrocarbons (PAHs). At an EPA Workshop on Ultrafine Particles on February 11, Michael Kleeman of the University of California presented new results from the California Teachers Study by B. Ostro et al., accepted for publication in *Environmental Health Perspectives*. Initial epidemiological results show a hazard ratio of 1.25 for ischemic heart disease from anthropogenic SOA. Research by Verma et al. has found that “photochemical transformations of primary emissions with atmospheric aging enhance the toxicological potency of primary particles in terms of generating oxidative stress and leading to subsequent damage in cells”[[8]](#footnote-8) and that “the oxidative potential was strongly correlated with organic carbon and PAHs.”[[9]](#footnote-9)

Delfino et al. strongly linked PAHs with mobile sources: “Indoor and outdoor PAHs (low-, medium-, and high-molecular-weight PAHs), followed by hopanes (vehicle emissions tracer), were positively associated with biomarkers, but other organic components and transition metals were not. … Vehicular emission sources estimated from chemical mass balance models were strongly correlated with PAHs (R = 0.71). … Traffic emission sources of organic chemicals represented by PAHs are associated with increased systemic inflammation and explain associations with quasi-ultrafine particle mass.”[[10]](#footnote-10)

How do PAHs created during combustion of aromatic hydrocarbons undergo long-range transport? Zelenyuk et al. found that they are trapped inside highly viscous semisolid OA particles and thus prevented from evaporation and shielded from oxidation. “In contrast, surface-adsorbed PAHs rapidly evaporate leaving no trace. The data show the assumptions of instantaneous reversible gas-particle equilibrium for PAHs and SOA are fundamentally flawed, providing an explanation for the persistent discrepancy between observed and predicted particle-bound PAHs.”[[11]](#footnote-11)

PAHs have been summarized by one leading researcher as: “carcinogenic, immunotoxic, neurotoxic, mutagenic, and endocrine disruptors.”[[12]](#footnote-12) Prenatal exposure to low levels of PAHs from ambient air pollution has been associated with multiple adverse effects, including developmental delay at age 3, reduced IQ at age 5 (effects similar to lead), symptoms of anxiety/depression and attention problems at ages 6–7, and ADHD behavior problems in children.[[13]](#footnote-13) At a time when the rising incidence of autism is increasingly linked to disruption by environmental factors, and when the mutagenic effect of PAHs is well established, reducing exposure to PAHs should be a high public health priority.

1. **Increased use of domestically produced renewable ethanol is essential to both objectives and would have additional co-benefits.**

Ethanol’s value for octane is not a new discovery. In fact, it was only the competition from tetraethyl lead that knocked ethanol out of that role a century ago. When lead was phased out, however, ethanol was not available in sufficient supply to provide a substitute. That is no longer true today. U.S. ethanol production has risen to roughly 15 billion gallons per year, and almost all gasoline sold today contains 10 percent ethanol. A phased increase to supply an E30 market, sufficient to supply the octane needed for higher-compression engines – reducing aromatics by 60%[[14]](#footnote-14) – is entirely achievable.

Renewable ethanol can be produced from multiple agricultural feedstocks; corn starch has been the principal source in the U.S. and sugar cane in Brazil. Decades of federal investment in research has made possible the conversion of cellulose – widely abundant material that gives plants their structural stability – and major new cellulosic ethanol facilities, representing billions of dollars of private investment, are now going into production from POET-DSM, Abengoa Bioenergy, and DuPont Danisco, using corn stover and other “waste” biomass feedstocks.

The demand for farmland to produce corn for ethanol has been mitigated by continuing increases in yield and by the diversion of the protein in corn to supply animal field. Increased use of conservation tillage has reduced soil erosion and water runoff while saving labor and fuel.

1. **The LCFS should fully reflect the latest research on the value of mid-level ethanol blends to reduce GHGs and benefit public health and the environment through the displacement of aromatics.**

The Energy Future Coalition and the Urban Air Initiative respectfully urge CARB to consider the role that mid-level ethanol blends could play in delivering a nationwide low carbon, high octane transportation fuels system.

* As a renewable fuel, reflecting its production and land use, ethanol offers substantial GHG reduction benefits relative to gasoline and particularly to aromatics. CARB should incorporate the latest values from Argonne’s life-cycle analysis into its calculations.
* In the fall of 2013, the World Health Organization’s International Agency for Research on Cancer (IARC) published its findings that traffic-related particulate matter emissions represented a Group 1 carcinogenicity threat to humans. WHO noted that in 2010, 223,000 worldwide deaths from lung cancer alone were attributable to air pollution, and singled out particulate matter and transportation-related pollution as a major source.
* Advanced GDI (gasoline direct injection) systems could make particle number (PN) emissions worse unless fuel composition is improved by reducing aromatic content. Mid-level ethanol blends have been shown to reduce particulate and black carbon emissions by 45 to 80% in direct injection and port fuel injection engines, respectively. Some have argued for the use of particulate filters on gasoline engines; however, the much smaller particles in gasoline exhaust (compared to diesel exhaust) elude capture by such filters, which also will interfere with, possibly even reverse, important fuel efficiency and carbon reduction gains.

The most important fuel quality improvement to achieve reductions in both carbon and particle-borne toxics emissions would be to substantially reduce aromatic hydrocarbons in gasoline. The need for octane can easily be supplied by cleaner-burning ethanol blends. They would:

1. Facilitate automaker compliance with tighter fuel efficiency and carbon reduction requirements.
2. Improve vehicle performance and reduce costs to the consumer.
3. Reduce harmful urban particulate matter, black carbon, and toxics emissions.
4. Provide market-based demand signals to meet national biofuels targets in a cost-effective manner.
5. Provide an alternative to ineffective and costly gasoline particulate filters.
6. Generate billions of dollars annually in carbon reduction and health savings co-benefits.
7. Reduce refinery crude oil usage and diversify the transportation sector away from reliance on crude oil.
8. Stimulate the rural economy and create new jobs.
9. Provide a more stable investment climate for next-generation biofuel technologies.
10. Simplify California’s path to low carbon fuels.

1. *See, e.g.*, Cynthia Williams, Ford Motor Company, Comments on Proposed Tier 3 Rule, EPA-HQ-OAR-2011-0135-4349, at 3 (July 1, 2013) (“strongly recommend[ing] that EPA pursue regulations . . . to facilitate the introduction of higher octane rating market fuels,” noting that they “offer the potential for the introduction of more efficient vehicles”). [↑](#footnote-ref-1)
2. M. Wang *et al*., “Well-to-wheels energy use and greenhouse gas emissions of ethanol from corn, sugarcane and cellulosic biomass for US use,” 2012 Environ. Res. Lett. 7 045905 (<http://iopscience.iop.org/1748-9326/7/4/045905>). [↑](#footnote-ref-2)
3. See Alverson, “Re-thinking the Carbon Reduction Value of Corn Ethanol Fuel” (attachment). [↑](#footnote-ref-3)
4. See the 2014 MathPro – GM/Ford/Chrysler linear program study, “Refining Economics of U.S. Gasoline: Octane Ratings and Ethanol Content” (attachment). [↑](#footnote-ref-4)
5. The European Programme on Emissions, Fuels and Engine Technologies, 1996 [↑](#footnote-ref-5)
6. Health Effects Institute Panel on the Health Effects of Traffic-Related Air Pollution, “Appendix B. Fuel Composition Changes Related To Emission Controls” in Special Report 17, “Traffic-Related Air Pollution: A Critical Review of the Literature on Emissions, Exposure, and Health Effects,” Chapter 2. Emissions from Motor Vehicles. 2010. <http://pubs.healtheffects.org/getfile.php?u=555> [↑](#footnote-ref-6)
7. K. von Stackelberg et al., “Public health impacts of secondary particulate formation from aromatic hydrocarbons in gasoline,” *Environmental Health* 2013, 12:19. <http://www.ehjournal.net/content/12/1/19> [↑](#footnote-ref-7)
8. V. Verma et al., “Redox activity of urban quasi-ultrafine particles from primary and secondary sources,” [*Atmospheric Environment*](http://www.sciencedirect.com/science/journal/13522310), 43(4), December 2009, 6360–6368. <http://www.sciencedirect.com/science/article/pii/S1352231009007857> [↑](#footnote-ref-8)
9. V. Verma et al., “Physicochemical and oxidative characteristics of semi-volatile components of quasi-ultrafine particles in an urban atmosphere,” [*Atmospheric Environment*](http://www.sciencedirect.com/science/journal/13522310), 45([4](http://www.sciencedirect.com/science/journal/13522310/45/4)), February 2011, 1025–1033. <http://www.sciencedirect.com/science/article/pii/S1352231010009301> [↑](#footnote-ref-9)
10. R. Delfino et al., “Association of Biomarkers of Systemic Inflammation with Organic Components and Source Tracers in Quasi-Ultrafine Particles,” *Environ Health Perspect*. 2010 Jun; 118(6): 756–762. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2898850/> [↑](#footnote-ref-10)
11. A. Zelenyuk et al., “Synergy between secondary organic aerosols and long-range transport of polycyclic aromatic hydrocarbons,” [*Environ Sci Technol*](http://www.ncbi.nlm.nih.gov/pubmed/23098132). 2012 Nov 20;46(22):12459-66. <http://www.ncbi.nlm.nih.gov/pubmed/23098132> [↑](#footnote-ref-11)
12. F. Perera et al., “The Relationship Between Prenatal PAH Exposure and Child Neurocognitive and Behavioral Development,” PowerPoint presentation, Sept. 2011. [↑](#footnote-ref-12)
13. F. Perera et al., “Early-Life Exposure to Polycyclic Aromatic Hydrocarbons and ADHD Behavior Problems,” PLOS ONE, November 5, 2014, DOI:10.1371/journal.pone.0111670.

    <http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0111670> [↑](#footnote-ref-13)
14. See the 2014 MathPro – GM/Ford/Chrysler linear program study, “Refining Economics of U.S. Gasoline: Octane Ratings and Ethanol Content” (attachment). [↑](#footnote-ref-14)