
ETHANOL WHITE PAPER

PREPARED FOR: REGIONAL AIR QUALITY COUNCIL
AIR QUALITY CONTROL COMMISSION
AIR POLLUTION CONTROL DIVISION
DENVER OZONE STAKEHOLDERS

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TOPIC: ETHANOL-BLENDED GASOLINE AND OZONE

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The presentation to the RAQC on September 6, 2007, identified the removal of the Clean Air Act's 1 psi RVP waiver for ethanol blended in gasoline ("Ethanol Waiver") as a potential ozone control strategy in the Denver Area Ozone Attainment Plan to be developed by the end of 2008. This same proposal was considered in the 2004 proceeding to adopt the Denver Area Ozone Early Action Compact ("Ozone EAC"). During the EAC proceeding, Ethanol Management Company ("EMC") retained experts on the air emissions and ozone effects of ethanol-blended gasoline to provide scientific information to the RAQC and the AQCC. (EMC was an ethanol wholesaler that recently merged with Frontier Oil Co.) The RAQC and the AQCC decided not to remove the Ethanol Waiver.

Many of the current members and employees of the RAQC, the AQCC, and the APCD did not participate in the Ozone EAC proceedings. This White Paper provides a "primer" on ethanol and ozone for those for whom this is a new issue. The fundamental science has not changed in the past two decades.

ERAS, Inc. has retained two nationally respected experts to answer questions that may arise on ethanol, ozone modeling and mobile source emissions during this proceeding:

- **Mr. Gary Herwick:** Mr. Herwick was formerly Director of Environment and Energy for General Motors Corporation and has 35 years of experience in automotive emissions control and fuels. He has served as emissions committee co-chair and member of the Board of Director of the Coordinating Research Council ("CRC"). The CRC has performed numerous studies on the effect of ethanol and other fuels on automobile emissions. CRC members include the American Petroleum Institute, the Society of Automotive Engineers, and automobile manufacturers. CRC's studies are relied on by the U.S. EPA, the California Air Resources Board ("CARB"), and other governmental agencies in the development of

mobile source fuel and emission regulatory requirements. (CV attached as Ex. 1.)

- Dr. Gary Whitten: Dr. Whitten has over 40 years of experience in the field of gas-phase photochemistry and is an expert on the CAMx model that will be used by the RAQC's contractor to model Denver-area ozone for the upcoming proceeding. Dr. Whitten developed a predecessor model to CAMx and recently updated the CAMx model's chemistry formula for ozone formation. (CV attached as Ex. 2.)

Summary of Current Scientific Evidence on Ethanol and Ozone

This summary is based on information from EPA, CARB, ENVIRON (state's ozone modeler for the EAC and proposed modeler for this proceeding), CRC and other sources which are not related to the ethanol industry and are considered to be objective on the issues related to ethanol-blended gasoline and emissions.

- **Gasoline Blends – E10 and E85:** In Colorado, ethanol is blended with gasoline at two different ratios: 10% ethanol/90% gasoline (“E10”) and 85% ethanol/15% gasoline (“E85”). APCD survey shows that E10 had an 85% market share during 2007 summer ozone season. Governor Ritter and the Colorado Office of Energy Programs have initiated an effort to expand service stations that sell E85 – currently 31 stations in Colorado.
- **Effect of Ethanol Blends on Mobile Source Emissions of Criteria Pollutants:** E10 reduces CO and VOC exhaust emissions, but increases NOx exhaust emissions and VOC evaporative and permeation emissions. E85 reduces CO and NOx exhaust emissions, but VOC permeation is less than conventional gasoline (E0) or E10. EPA, “Regulatory Impact Analysis: Renewable Fuel Standard Program,” Ch. 3, at p. 153, 156-157 (EPA420-R-07-004, April 2007) (attached as Ex. 3).
- **Clean Air Act 1.0 psi RVP Ethanol Waiver:** Section 211 of the federal Clean Air Act (42 U.S.C. 7545) sets motor vehicle fuel specifications applicable in attainment and nonattainment areas. Section 211(h)(1) requires the use of gasoline during the high ozone season (May 1 – Sept. 15) with a maximum Reid Vapor Pressure (“RVP”) of either 9.0 or 7.8 psi. Section 211(h)(4) of the Clean Air Act allows gasoline-ethanol blends containing 9-10 percent volume ethanol a 1.0 psi higher vapor pressure than that established for gasoline. In the Denver area, this means that E10 may have an RVP of 8.8 psi (7.8 psi base plus 1 psi from 10% ethanol).

- **E10 Reduces CO and Increases VOC Emissions (Compared to E0) with a Net Neutral Effect on Ozone**
 - **Chemistry Basis for E10’s Ozone-Neutral Effect:** As explained in the following reports, both CO and VOC contribute to the formation of ozone. E10 reduces CO emissions by several times its increase in VOC emissions. The CAMx model demonstrates that the net effect on ozone formation is neutral.
 - **National Research Council (“NRC”) 1999 Report:** In a 1999 report done under contract for EPA, the NRC concluded: “[T]he contribution of carbon monoxide (CO) to ozone formation should be recognized in assessments of the effects of RFG [reformulated gasoline required by EPA for certain ozone nonattainment areas].” NRC, “Ozone-Forming Potential of Reformulated Gasoline,” at p. 6 (1999).
 - **EPA 2001 Decision Approving Increase in Ethanol for Milwaukee-Chicago:** In 2001 EPA concluded that ethanol-blended fuel is essentially “neutral” towards summer ozone formation in the Milwaukee-Chicago area and approved an increase in the RVP for RFG with a 10 percent ethanol-blend. EPA stated: “We believe that IEPA’s [Illinois EPA] photochemical modeling reasonably supports a finding that the level of CO decrease likely to occur in the Chicago and Milwaukee areas will offset the potential ozone air-quality impacts of a 2.0 percentage point adjustment to the VOC performance standard. . . .” 66 Fed. Reg. 37156, 37161 (July 17, 2001).
 - **ENVIRON 2005 Denver-Area CAMx Modeling Concluded 100% E10 Market Share Would Not Increase Ozone:** ENVIRON’s modeling on the effect of ethanol on ozone for the EAC was deemed invalid. Following adoption of the EAC, to resolve this issue EMC retained ENVIRON to use the EAC model and emissions inventory to model E10 market shares of 0% and 100%. ENVIRON’s report (attached as Ex. 4) concluded: “What small changes in ozone that were estimated suggested the use of the ethanol blend would produce small, but immeasurable, reductions in ozone concentrations in the DMA.”
 - **EPA Ozone Modeling for Renewable Fuel Standard (“RFS”) (April 2007):** EPA’s recent RFS modeling of the ozone effects of ethanol-blended fuel supports ENVIRON’s conclusion of E10’s ozone-neutral effect. EPA’s modeling of the RFS concluded: (a) The average ozone impact for all areas is 0.057 ppb, or about 0.06% of the ozone NAAQS (80.0 ppb). (b) The average change

for areas with significant increases (greater than 50%) in ethanol use between now and 2015 is 0.153 ppb. However, EPA notes the caveat that its modeling did not include the CO reduction factor, which would reduce modeled ozone levels in areas where ozone formation is VOC-limited. This caveat would apply to the Denver area, which was determined to be VOC-limited during the EAC process. EPA, “Regulatory Impact Analysis: Renewable Fuel Standard Program,” Ch. 5, at pp. 204 – 208 and Ch. 10, at p. 10-35 (Environmental Defense comments on EPA’s ozone modeling) (EPA420-R-07-004, April 2007) (attached as Ex. 5).

- **CARB Predictive Model Revised June 2007:** CARB’s Predictive Model allows refiners to formulate gasoline to meet California low-emitting reformulated gasoline (CARFG3) requirements. The Predictive Model is a set of equations in an Excel spreadsheet that relates exhaust rates of VOCs, NO_x, and toxic emissions to values of eight regulated properties (RVP, benzene, sulfur, etc.) of gasoline. The June 2007 update incorporates current emission data and statistics.

The Predictive Model can be used with a compatible model known as “CARBOB” to determine the properties that “before ethanol” fuel must have to meet the CARFG3 standards after a prescribed amount of ethanol is added. It shows the values of gasoline that the refiners can ship (before ethanol is added) because ethanol cannot be added at the refinery if the fuel is to be transported via pipeline. The CARBOB model incorporates four important facts about ethanol blended with gasoline: First, properties of gasoline like aromatics, olefins, sulfur, and benzene are merely diluted by ethanol. Second, 10% ethanol adds 1 psi to the RVP. Third, T50 is lowered for E10 compared to E0 by about 7 points for typical fuels. Fourth, T90 is lowered by about 4 points.

Dr. Whitten’s preliminary calculations using the Predictive Model and CARBOB to predict the percentage change in emissions due to blending of ethanol to E10 show: Starting with an E0 at 7 psi RVP and adding 10 percent ethanol gives an 8 psi RVP fuel that has a combined ozone-forming potential of VOC and CO that is essentially unchanged. Note that the models include permeation. (Dr. Whitten’s opinion is that the CAM_x model should show slightly lower ozone-forming potential because the MIR reactivity factor used in the Predictive Model under-represents the ozone-forming potential of CO.) The Predictive Model spreadsheet indicates that: (a) CO emissions decrease by 17.5 percent going from E0 to 10; (b) NO_x increases by 4 percent; and (c) potency-weighted toxics decrease by about 7 percent. (To apply these

models specifically to Denver, there would need to be a determination on the average fuel properties sold in Denver.)

- **Emission Inventory Model (MOBILE6.2) Does Not Incorporate Most Recent Data on E10's Effects on Mobile Source Emissions:** The APCD is developing an emission inventory for the Denver area of stationary sources, area sources, mobile sources, etc. using EPA's MOBILE6.2 model as input for the ozone model, CAMx. MOBILE6.2 has not been updated to incorporate the following data on ethanol impacts:
 - **Permeation:** Permeation is the migration of (VOC) fuel molecules through (plastic) fuel system components. E10 increases permeation compared to conventional gasoline.
 - **CO Reductions in Newer Model Vehicles:** Recent data shows greater CO reductions in newer vehicles.
 - **Sulfur:** Lower sulfur fuel concentrations decrease emissions.
 - **VOC:** E10 reduces VOC exhaust reductions in newer model vehicles. (See Ex. 3).
- **E85 Greenhouse Gas Emissions:** 22% lower from corn. 91% lower from cellulose (life cycle analysis). Source: Sarah Dunham, Director, EPA Transportation and Climate Division, March 28, 2007 (PowerPoint).
- **Low Carbon Fuel Standard ("LCFS"):** EPA plans to propose LCFS in November or December 2007. California is developing LCFS that will reduce carbon in fuel by 10% by 2020. Ethanol fuel (both E10 and E85) will be necessary to meet federal and state LCFS requirements. (CARB Presentation to AQCC, California's Low Carbon Fuel Standard, Sept. 13, 2007).
- **Dr. Stedman's "High Temperature" and "False Failures" Theories:** Dr. Stedman criticized the ENVIRON 2005 study on the grounds that MOBILE6.2 does not properly simulate the increase in emissions at high ambient temperatures:
 - **ENVIRON's Response to High Temperature Theory:** "The EPA MOBILE6 model is based on thousands of mobile source emission measurements. . . . It should be noted that when we modeled a 2003 episode the Colorado APCD provided on-road mobile source temperature emission adjustment factors to account for the effects Dr. Stedman alludes to, however they resulted in small (few percentage) increases in emissions not the

- **Response to “False Failure” Theory by Jerry Gallagher, former Director of APCD Mobile Sources Program, (Feb. 2004) (attached):** No evidence that “false failures” by 10 vehicles of IM-240 test were due to ethanol: Only 2 of the 10 vehicles were burning ethanol-blend. Also, studies have shown that false failures likely result from faulty test method.
- **Recommendations to Resolve Issue of E10 and Ozone:**
 - **Recommended Approach:** The Denver area emissions inventory and the CAMx model have not changed significantly since ENVIRON’s 2005 modeling. Dr. Whitten has advised that updating MOBILE6.2 with the more recent emission factors is unlikely to change the results significantly. The CARB Predictive Model estimates essentially the same result. The RAQC and the AQCC have sufficient grounds at this point to conclude that removing the Ethanol Waiver would not be an effective ozone control strategy.
 - **Alternative Approach:** If the agencies decide that it is necessary to remodel E10’s impacts on ozone, the RAQC contractor should run the CAMx ozone model at 7.8 psi RVP with and without the Ethanol Waiver for comparison. If the agencies are considering lowering the RVP, the RAQC contractor should also run the CAMx ozone model at 7.0 psi RVP with and without the Ethanol Waiver for comparison. To avoid future speculation about the effect of MOBILE6.2’s lack of the most updated emission factors, the agencies should consider modifying the MOBILE6.2 emission inventory to incorporate the latest data on permeation, emissions from newer model vehicles, sulfur, etc. Tom Darlington of Air Improvement Resources, Inc. (AIR), formerly with EPA, has done these types of MOBILE6.2 updates with EPA’s approval. See Ex. 3, at p. 144.