Summary of the Ethanol Forum and Technical Roundtable

Convened by the

South Coast Air Quality Management District, July 15, 2006

Prepared for

South Coast Air Quality
Management District

21865 E Copley Dr

Diamond Bar, California 91765

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Prepared by
Michael D. Jackson
Jonathan H. Leonard
TIAX LLC
1601 S. De Anza Blvd., Suite 100
Cupertino, California 95014-5363
Tel 408 517-1550
Fax 408 517-1551

TIAX Case D0374

Table of Contents

Executive Summary

The South Coast Air Quality Management District (SCAQMD) convened a technical forum and roundtable discussion on the issues of using ethanol as an oxygenate in California phase 3 reformulated gasoline (CaRFG3). Experts from state and local agencies, interested stakeholders, and industries representing oil, auto, and ethanol were invited to a one day meeting on June 15, 2006 at the SCAQMD in Diamond Bar, California. Presentations by experts were given, followed by a roundtable discussion.

Presentations focused on low level ethanol blends—5.7% to 10% volume mixtures with gasoline blendstock, and neat uses of ethanol in flexible fuel vehicles (FFVs). CaRFG3 contains 5.7% ethanol combined with a gasoline blendstock that meets California requirements for reformulated gasoline. E85 or neat ethanol is a mixture of 15% gasoline and 85% ethanol also meeting California specifications. The issues associated with low level blends and E85 were the focus of the June 15th meeting.

Low Level Ethanol Blends

Ethanol as a gasoline blend component has been used by the refining industry since the oil crisis of the 1970's. Use in California's reformulated gasoline, however, did not occur until the additive methyl tertiary butyl ether (MTBE) was banned by California's Governor starting in 2004. The refining industry responded by backing out MTBE and phasing in ethanol starting in 2003. Substantial research was performed in the early 1990's by the auto and oil industries to determine how to reformulate gasoline to reduced criteria and ozone forming pollutants as well as toxic emissions. Adding blend components containing oxygenate was found to be beneficial in reducing hydrocarbons (and toxics), oxides of nitrogen (NO_x), and carbon monoxide from the existing fleet of vehicle technologies. Most of this work was performed using MTBE and little research was performed on the effects of different oxygenates.

Recent emissions testing on early and late model vehicles have shown that emission performance of these vehicles depends on whether MTBE or ethanol is used. Permeation emissions for ethanol are considerably higher than for MTBE-containing gasoline. Exhaust emissions of NO_x are also different but only slightly in comparison to permeation, while CO emissions are lower. The California Air Resources Board (ARB) is using these data to update the predictive model. Refiners use the predictive model to produce Phase 3 compliant gasolines, so changes in the model may affect their flexibility and economics. ARB on the other hand is required by state law to not implement control measures that increase emissions. How these issues are resolved was a major part of the discussion.

All presenters acknowledge the increased emissions associated with permeation. SCAQMD suggested that commingling—ethanol containing gasoline mixed with MTBE containing gasoline—and permeation could have been one of the causes for increased ozone levels in the South Coast Air Basin in 2003. Preliminary estimates of the evaporative impact of ethanol vs. MTBE due to permeation in 2005 are 26 tpd in the South Coast Air Basin and 78 tpd statewide.[1] This increase in hydrocarbon emissions is significant and ARB is looking for ways to mitigate. ARB will be evaluating both fuels and non-fuel options, although the oil and auto industries questioned ARB's authority to implement non-fuel strategies. One fuel strategy is to eliminate ethanol use during the smog seasons in California—effectively eliminating use during the hotter summer months. Such a strategy would be difficult for both the refining and ethanol industries to implement. Such a strategy could negatively impact fuel supply and distribution in the state, limit refining flexibility and create ethanol supply and distribution problems, although the scope of such impacts is uncertain in the absence of a detailed study of this issue. Another strategy is to offset the higher emissions using other control measures like vehicle scrappage. Nevertheless, ARB will be modifying the predictive model to include permeation emissions and to ensure overall emission benefits of reformulated gasoline. Changes in the predictive model will have to balance benefits with the producibility of reformulated gasoline in California.

The predictive model also needs updating on both exhaust and evaporative emissions. Recent testing on more modern vehicles has provided additional data on the performance of ULEV and SULEV technologies to various reformulations of gasoline volatility and ethanol content. The results of these tests showed that there are benefits of reformulated gasoline with ethanol but that the response of these very low emission technologies was very complicated. For example, hydrocarbon (HC) emissions increase with higher ethanol blends for the higher T90 distillation temperatures but decreased or stayed the same at the lowest T90 tested. Similar very complicated responses were also seen for CO and NO_x. This is in contrast to previous testing which generally showed HC and CO reductions and slight NO_x increases with ethanol content.

ARB and industry are currently working to develop new emissions inventory estimates and Predictive Model correlations using both the new and old data sets. ARB stressed and industry also emphasized that it is very important to allow adequate time to address stakeholder concerns in order to get the science right on the predictive model update and on estimates of emission inventories. California's air quality and the use of reformulated gasoline using ethanol depend on the success of these efforts by ARB and industry.

Table 1 summarizes the issues and findings of the forum and roundtable for low level ethanol blends.

[1] ARB's current estimate of on-road permeation emissions increase statewide in 2015 is 14 tpd. See "Mobile Source Emissions Inventory Workshop—On-Road Motor Vehicles, EMFAC2007 Working Draft", September 11, 2007 http://www.arb.ca.gov/msei/workshop20060911/onrddkp_6.pdf

Table 1. Issues and Findings for Low Level Ethanol Blends in Reformulated Gasoline

Low Level Blend Issues	Findings
▪ Permeation	✓ Significant in near term and in out years: estimated on and off-road HC increase in SCAB: 26 tpd (2005) and 14 tpd (2020) ✓ Permeation emissions double for each 10°C ✓ No known retrofit technology ✓ ARB will incorporate in Predictive Model ✓ Mitigation of on and off-road emissions may require more than fuel strategies
▪ Predictive Model Accuracy / Robustness	✓ Current data set is heavily skewed with old vehicle and fuels data ✓ New data on ULEV and SULEV show complicated interaction between gasoline volatility and ethanol ✓ Update should make sure science is right—model can have big effect on emissions as well as economic viability of reformulated gasoline ✓ 10% ethanol blends show an increase in NOx emissions
▪ Mitigation strategies	✓ ARB required by state law to ensure control measures do not increase emissions—e.g. the permeation emissions impact of the transition from Phase 2 to Phase 3 California gasoline must be mitigated. ✓ ARB will evaluate both fuel and non-fuel strategies to mitigate emission increases ✓ Predictive model could provide fuel strategy if resulting reformulated gasoline is economic ✓ Summertime zero ethanol policy is fuel strategy but would not be favored by refining or ethanol industries ✓ It's not clear that fuel offset requirements alone will be sufficient.
▪ CO / HC tradeoffs	✓ Ethanol industry suggests that HC increases are fully offset by CO reductions if CO reactivity is adjusted as proposed by the ethanol industry. ✓ ARB is updating its analysis and the predictive model but do not expect for CO reactivity to completely offset permeation increases
▪ Commingling	✓ Commingling of ethanol in non-ethanol blends recognized as resulting in higher RVP and potentially higher evaporative emissions and could have been partially responsible for SCAB's high ozone in 2003
▪ Certification test fuel	✓ Current gasoline certification based on MTBE (Phase 2) hence reason for permeation surprise ✓ Auto manufacturers view any change in certification as major ✓ PZEV certification requirements are currently a barrier to E-85 FFV certification, although efforts are underway by manufacturers to address this issue.
▪ Greenhouse Gas Benefits	✓ Corn-based ethanol offers 23% GHG benefits ✓ Cellulosic feedstocks offer 75-80% GHG benefits

E85

Fuel ethanol (E-85) use in vehicles has also been researched in California since the 1980s. Auto manufactures have developed FFVs that can use gasoline, E85, or any mixture of gasoline and E85. FFVs are designed to accommodate this entire range of fuels and comply with the applicable exhaust and evaporative requirements. Limited data suggest that like gasoline FFVs may also have increased permeation emissions. Material changes to fuel system materials may considerably reduce permeation emissions, although reaching zero permeation remains a significant challenge.

In the recent CRC E-65-3 study one FFV was tested and showed roughly ½ the permeation emissions when operated on E85compared to E0, while E10 was approximately twice that found with E0. So permeation emissions can still be an issue with FFVs especially if these vehicles are operated on low level blends. There is also a lack of exhaust and evaporative emission data and industry is developing programs to test more FFVs over various mixtures. There has been little in-use testing of FFVs.

The biggest issue with E85 is lack of fueling infrastructure. State agencies would like to see E85 become commercial since its use is projected to provide reduction in greenhouse gas emissions and its use will reduce petroleum consumption. However, it was not clear to the participants what the business case was for an infrastructure to develop and what the value proposition is for the consumer. Ethanol is currently priced as a blending component with long term contracts accounting for 90%+ of wholesale transactions. Although spot prices in 2006 are around $4 per gallon, it is anticipated that these increases may decline over the next 12 months as supply increases, according to sources in the fuel industry. In order to present an attractive consumer value, E85 would have to be priced on an energy basis (about 72% of gasoline).

General Motors is currently the only auto maker for the 2006 model year that is certifying and selling FFVs in California. Other OEMs may reenter the California market but lack of vehicles meeting the California PZEV standard could become a barrier to E85 use in the state.

ARB and CEC, as well as SCAQMD, stressed that current corn to ethanol production provides only a smaller (23%) improvement in climate change emissions and that ultimately cellulosic ethanol is needed for ethanol use to be a major strategy in reducing greenhouse gas emissions. California has aggressive goals to use more biofuels and alternative fuels in transportation. The Governor and legislature have both developed policies to encourage the use of alternative fuels such as E85.

Table 2 summarizes the issues and findings of the forum and roundtable around E85.

Table 2. Issues and Findings for E85 Transportation Fuels

E85 (Fuel Ethanol)	Findings
▪ E85 Infrastructure	✓ Only 1 retail station in California ✓ Consumer value proposition for using E85 ✓ Business case to install infrastructure ✓ Cost of infrastructure and transition throughout state ✓ Early joint ventures between oil companies and ethanol producers to establish fueling stations underway ✓ Need enhanced vapor recovery systems for ethanol ✓ Since a majority of FFV's on the road will have On-board Vapor Recovery, the need for Stage II vapor recovery is being assessed
▪ Prices	✓ E85 is a harder business case than low level blends under current commercial market economics ✓ Incentives likely to be needed in short and medium term
▪ Supply Availability	✓ Current U.S. ethanol production stands at 4 billion gallons ✓ Industry expects to exceed the 2012 RFS goal of 7.5 billion gallons within the next 2 years; unconfirmed estimates may be in the range of 15-20 billion gallons, although further assessment of this issue is needed. ✓ Uncertainty exists on the upper limit above which food, soil and water resources severely affected by diversion of corn to ethanol
▪ Availability of FFVs	✓ GM is the only 2006 manufacturer in California ✓ Will OEMs produced advanced FFVs meeting PZEV standards
▪ Emission Benefits of FFVs	✓ Essentially no in-use testing data for FFVs ✓ Catalyst durability for consistent aldehyde control needs in-use confirmation ✓ MIR reactivity studies somewhat outdated ✓ Need for testing of latest model FFVs ✓ One permeation test point expected under CRC project E-65-3
▪ FFV use of commingled fuel	✓ Current FFV designs are certified to comply with exhaust and evaporative requirements on E-85 and E-10. ✓ In the early transition years (e.g., through 2020) however, the lack of widespread E85 station availability will likely result in some commingling of gasoline and E85 reducing the maximum benefit of E85 ✓ The role of older FFVs may remain an issue during this transition period, as new technology vehicles which meet near-zero and PZEV standards are phased into the fleet.
▪ Permeation emissions	✓ Permeation emissions are expected to decline to very low levels as vehicles with newer evaporative controls come to dominate the fleet. [2]
▪ Climate Change Emissions	✓ Larger potential GHG emission benefits than low level blends ✓ Corn-ethanol pathway provide 23% GHG benefits ✓ Cellulosic ethanol pathway provide 75-80% GHG benefits ✓ California pursuing biofuels production and use

[2] Data on one FFV shows an increase in permeation emissions when tested on E10, compared to E0. The latest CRC report (E-65-3) shows that E85 permeation was half that of E0. It is likely, therefore, that FFVs will show an increase in permeation with low level ethanol fuels compared to E0 or MTBE fuels.

1. Introduction

On June 15, 2006 the South Coast Air Quality Management District (SCAQMD) convened a technical and policy forum on the use of ethanol as a transportation fuel. The objective of the meeting was to identify key expert perspectives on the energy and emission implications of the use of ethanol in order to identify appropriate oxygenated policy in the context of the upcoming revisions to the Air Quality Management Plan (AQMP) for the South Coast Air Basin.

SCAQMD Board and staff are concerned with possible emissions increases associated with emerging fuels including the use of ethanol as an oxygenate in California reformulated gasoline. The South Coast Air Basin is classified by the U.S. Environmental Protection Agency (EPA) as an extreme non-attainment area for ozone and is also in non-attainment for $PM_{2.5}$. As such, SCAQMD will need to substantially reduce hydrocarbon (HC), oxides of nitrogen (NO_x), and direct and secondary emissions of fine particulate manner ($PM_{2.5}$) in order to achieve ambient air quality standards.

Ethanol is currently blended in with "California reformulated gasoline blendstock for oxygenate blending" or "CARBOB." The CARBOB formulations currently produced at refineries servicing the California light-duty vehicle marketplace are designed to be blended with ethanol to give a blend composition having 5.7% ethanol and meeting the Air Resources Board's (ARB's) specifications for Phase 3 Reformulated Gasoline. California's RFG3 (CaRFG3) establishes gasoline "flat limit" properties such as benzene, sulfur, aromatic hydrocarbon, olefin, and oxygen content in order to reduce the emissions impact of on-road, light-duty vehicles. Refiners can meet the regulations by producing gasoline that meets flat or averaging limits or by using ARB's Predictive Model provided cap limits are not exceeded.

The Predictive Model provides refiners flexibility in meeting CaRFG3 by not having to meet the flat or averaging limits, but gives equivalent emission performance to gasoline meeting the flat or averaging limits. The Predictive Model is a complex set of relationships defining the emissions performance for various vehicle technologies existing in the California fleet. A refiner inputs the properties of its candidate gasoline into the Predictive Model and the model calculates the predicted emissions from this candidate fuel. If the predicted percent change in emissions between the candidate fuel and a fuel that meets the CaFRB3 specifications (reference fuel) are less than 0.04% for each pollutant regulated (NO_x, ozone forming potential or exhaust hydrocarbons, and potency-weighted toxics), then the candidate fuel is considered equivalent to the reference fuel.

There are a number of environmental issues associated with ethanol use as a transportation fuel. These are of concern to SCAQMD and other regulators such as ARB, so these were specifically explored in this technical forum-roundtable meeting:

- Increased permeation emissions (as defined as hydrocarbons) from vehicle fuel systems when ethanol is used compared to MTBE or no oxygenate

- Impact of ethanol use on air quality in the SCAB and effects on meeting ambient air quality standards
- Whether ARB's update of the Predictive Model will fully capture the increased on and off road permeation emissions and, if not, how will the increased emissions be mitigated
- Significance of lower carbon monoxide emissions on ozone formation and potentially offsetting higher HC emissions from permeation
- Benefits of corn-based ethanol on global warming emissions

SCAQMD pulled together a number of experts to address these issues. Table 3 shows the agenda for the June 15th meeting and the invited roundtable members. The agenda was divided into three segments: context and framing of issues, formal forum presentations, and roundtable discussion. The California Energy Commission and SCAQMD provided presentations on the context and framing of issues. A spectrum of presenters then provided views on the use of ethanol as a transportation fuel. Views represented the auto, oil, and ethanol industries, emission researchers, and ARB and SCAQMD. TIAX LLC was responsible for documenting written and oral content from the roundtable, moderating the roundtable discussion, and writing a report summarizing the findings of the meeting.

The roundtable discussion was meant to provide any of the invited participants or the audience the opportunity to ask questions of any of the presenters. Presenters were provided several questions in advance of the meeting that could be used to promote discussion among invited presenters. These questions are shown below for low level blends and E85 fuel:

Low-Level Blends

1) What options exist to fully mitigate the 42 tons per day of extra VOC emissions in the South Coast Air Basin resulting from the permeation emissions associated with low level blends?
2) What would be the gasoline supply impact of eliminating the use of ethanol during summer months?
3) What research priorities do you see relative to low-level ethanol blends and for E85?
    a) *For example, what commingling scenarios need better characterization?*
    b) *What are the prospects for demonstration and commercialization of optimized FFV's with plug-in hybrid capacity, such as the Saab 9-3 plug-in hybrid E100 prototype?*

Assuming the Predictive Model does not fully offset the permeation emissions associated with E-5.7 use due to permeation, what Air Quality Management Plan strategies should be considered to address this portion of the "black box" of needed emission reductions to attain federal and state air quality standards for both ozone and fine particulate?

Table 3. Ethanol Forum and Technical Roundtable Agenda

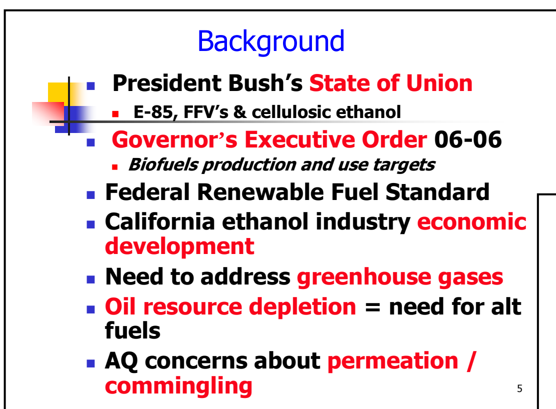
South Coast Air Quality Management District Headquarters — Room GB

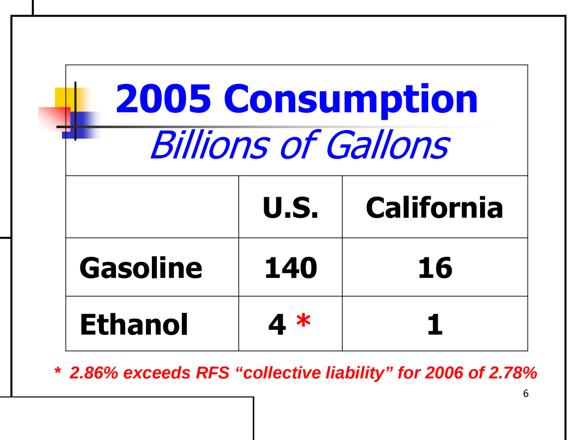
9:00 a.m.	**I.**	**Welcome**	Barry Wallerstein, SCAQMD
9:05	**II.**	**Self-Introductions**	
	III.	**Context and Framing of Issues:**	
9:10		Ethanol Outlook: Governor's Executive Order on Biofuels (06-06) & AB 1007 Alternative Fuels Plan	Peter Ward California Energy Commission
9:20		Ethanol Issues in the Context of the Air Quality Management Plan	Joe Cassmassi, SCAQMD
9:30		BREAK (20 MINUTES)	
	IV.	**Formal Forum Presentations** (10-15 minute presentations & Q&A)	
9:50	1)	Status of Predictive Model update & ARB Perspective	Bob Fletcher, ARB
10:10	2)	Summary of E-67 Study	Tom Durbin CE-CERT, U.C. Riverside
10:30	3)	Permeation test results	Harold Haskew, HH & Assoc.
10:50	4)	Latest CRC Study Plans re: ethanol (E-0 to E-85)	Mike Ingham, Chevron
11:10		BREAK (20 MINUTES)	
11:30	5)	Ethanol in the South Coast Air Basin	Gary Whitten, Smog Reyes
11:50	6)	Ethanol: A Viable Transportation Fuel for California	Gary Herwick Transportation Fuels Consulting
12:10 p.m.	7)	Ethanol Use in the Future: Important Considerations	Gina Grey Western States Petroleum Association
12:30 – 1:30		Lunch	
1:30	8)	Auto Industry perspective	Ellen Shapiro, Auto Alliance
1:50	9)	Oxygenate Issues and Options	Paul Wuebben, SCAQMD
2:10		**Roundtable Discussion** (previous 11 speakers)	
		Moderator: Mike Jackson, TIAX	
4:00		**Public Comment**	
		Summary / Next Steps	Mike Jackson, TIAX

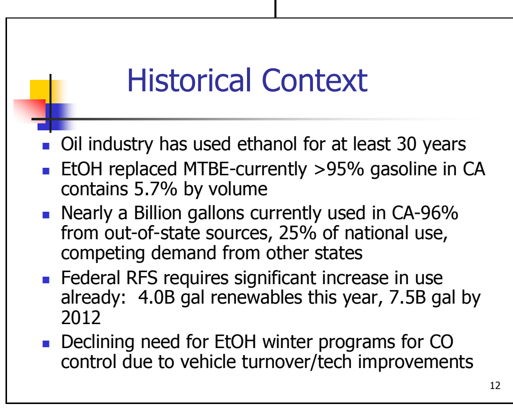
Fuel Ethanol (E85)

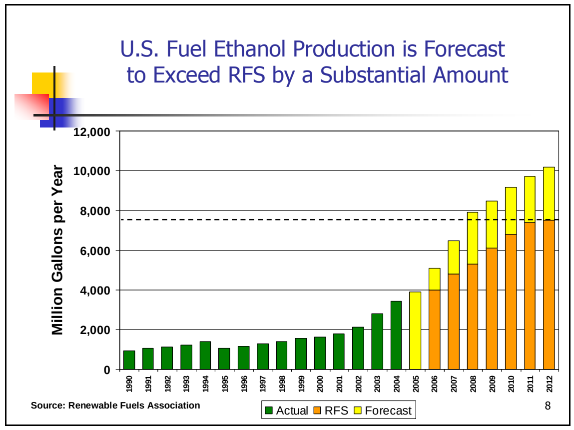
1) What can be done to expedite the development and use of Enhanced Vapor Recovery systems for E85?
2) What policies should be encouraged regarding the use of Flexible Fuel Vehicles during the early stages of E85 station deployment?

Interest and investments in ethanol use have increased substantially over the last year as oil prices have reached beyond $70 per barrel. Ethanol was previously introduced by the oil industries as a response to the oil crisis in the 1970's. Recently President Bush called for increased use of ethanol as petroleum displacement strategy. Governor Schwarzenegger has set biofuels production and use goals. California is using today about one billion gallons of ethanol in CaRFG3. The federal government developed a renewable fuel standard requiring 7.5 billion gallons used by 2012. As shown by the inserted chart there is considerable growth in ethanol production. But ethanol's production even with the Federal RFS is small in comparison to U.S. or California gasoline production. The ethanol industry expects to meet and exceed the Federal RFS for ethanol.









This report is meant to capture the views of the various experts in attendance at this meeting. We have attempted to summarize the meeting through meeting notes that outline each presentation, questions and answers, selective use of graphics presented at the meeting, and subsequently by synthesizing the major points and conclusions that we thought were reached during the meeting.

This report is organized as follows. Section 2 summarizes the issues and discussions surrounding low level ethanol blends. Section 3 outlines the issues and discussions around E85 and vehicle technologies to use this higher level blend of ethanol. Section 4 deals with petroleum displacement and climate change emissions for ethanol. Section 5 provides some concluding remarks on the use of ethanol as a transportation fuel in California.

Presentations are on the SCAQMD web site: http://www.aqmd.gov. To navigate the SCAQMD web site use the search feature and search for "technical forum." Click on the technical forum result. This will provide agenda and presentations from several forums held at the district. Choose the June 15, 2006 Ethanol forum or use the link below:

> http://www.aqmd.gov/tao/ConferencesWorkshops/06_EthanolWS/Ethanol_Forum_Agenda.htm

2. Low Level Ethanol Blends

Ethanol is currently blended at gasoline terminals with a gasoline blend stock produced by oil refineries. The gasoline blend stock or CARBOB needs to meet California standards for Phase 3 reformulated gasoline (CaRFG3). CARBOB can be shipped in pipelines to various terminals, whereas ethanol and CaRFG3 are shipped to and from the terminals by rail and tanker trucks. Because ethanol is a polar molecule, ethanol and blended ethanol gasoline fuels will pick up water and will lead to problems in the pipeline distribution system. Phase 3 RFG was introduced in 2002 and 2003 as the oxygenate MTBE was phase out of California due to ground water contamination.

ARB has a predictive model to provide refiners with flexibility in meeting RFG standards. The combination of RFG and subsequent improvements in catalyst emissions control technologies has resulted in today's light-duty vehicles having significantly lower HC, CO, NO_x, and toxic emissions. RFG lowers the emissions of existing vehicles in the California fleet and has enabled the introduction of modern emissions control systems that result in extremely low emission performance technologies like super ultra-low emission vehicles (SULEVs) or partial zero emission vehicles (PZEVs).

However, several issues have been discovered with RFG that uses ethanol to meet the oxygenate requirement. By far the biggest concern is with increased evaporative emissions (hydrocarbons and toxics) associated with permeation from fuel system components like fuel tanks and fuel hoses. Ethanol behaves very different from MTBE when mixed with gasoline and results in much higher permeation emissions.

ARB is currently evaluating how to update the Predictive Model to possibly account for these increased permeation emissions, or to find another approach to mitigate the increase in emissions. They are also updating the model based on newer test data provided by auto manufacturers and other organizations like the Coordinating Research Council (a joint auto oil organization). CRC has recently published data on the behavior of ethanol blended gasoline and is proposing future work to add to this data set.

Substantial improvement in air quality (levels of maximum ozone and number of days exceeding the national ambient air quality standard for ozone) have been achieved in the South Coast Air Basin. This has been accomplished with substantial control of stationary sources and continued improvement in vehicle technologies. SCAQMD is currently developing a plan to meet national ambient air quality standards (NAAQS) for ozone and $PM_{2.5}$. Increased emissions due to CaRFG3 will require additional reductions in the basin to achieve attainment.

This section outlines the presentations, discussion, and agreements that were reached by the participants in this meeting.

2.1 Air Quality Impacts

There were two presentations that addressed impacts of ethanol blends on ambient air quality. Joe Cassmassi (SCAQMD) presented on the issues of ethanol use in the context of the current AQMP. His presentation focused on the possible higher ozone levels that are occurring due to ethanol use in RFG. Gary Witten (Smog Reyes) argued in his presentation that ozone is unchanged since CO decreases resulting from ethanol RFG use in the California fleet offset HC increases associated with permeation emissions. This section addresses the issues raised by these two presenters and subsequent discussion by other participants.

Figure 1 taken from Cassmassi presentation shows the history of ozone—both days exceeding the 1-hour standard and concentration—in the South Coast Air Basin. The time frame shown is from 1999 to 2005. Until 1999 continuing progress was made in lowering days exceeding and ozone concentration. From 1999 to 2001 levels and days exceeding remained fairly flat. Then in 2002 and 2003 there was an increase in both exceedence days and ozone concentration. Trends in 2004 and 2005 were again lower than in 2002 and 2003 mostly due to metrological conditions.

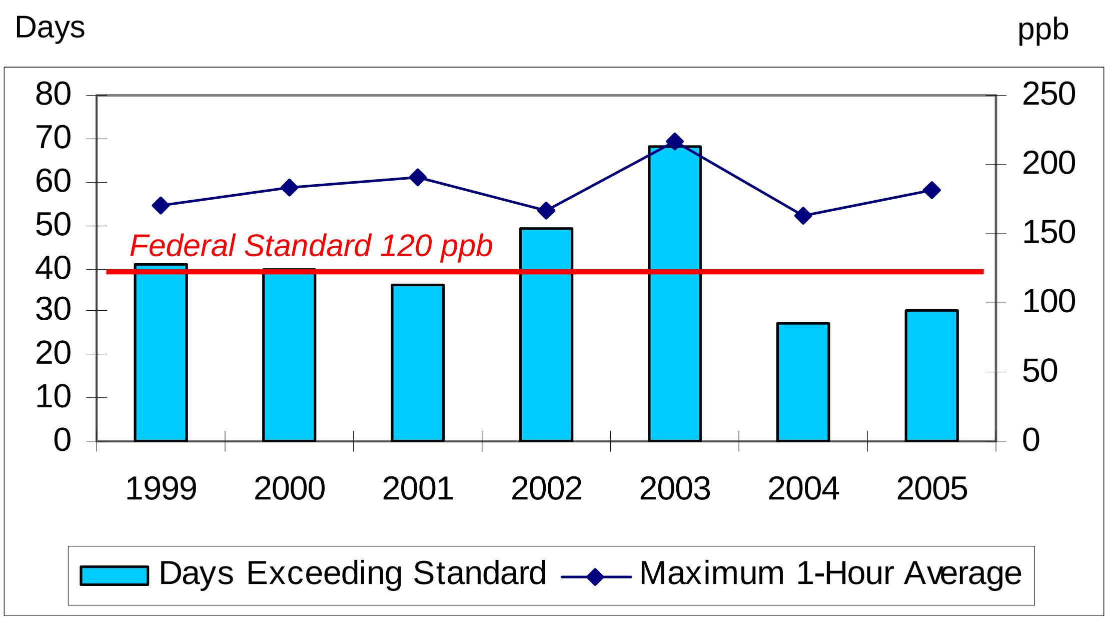


Figure 1. Ozone History in the South Coast Air Basin

The SCAMQD investigated the possible reasons for the bump up in ozone in 2002-03. They concentrated on 2003. Observations they made were: 2003 was the highest ozone concentration since the mid 1990s; 2003 was an exceptionally warm-stagnant year; commingling of ethanol and MTBE RFG increased evaporative emissions; and permeation emissions added to the evaporative emissions. Sensitivity analyses performed by SCAQMD modelers indicated that commingling and permeation emissions could contribute approximately 10 to 20 ppb ozone in 2003. Cassmassi noted that this is a significant impact in the basin and if these levels of emissions continue it will be very difficult for SCAQMD to achieve NAAQS for ozone.

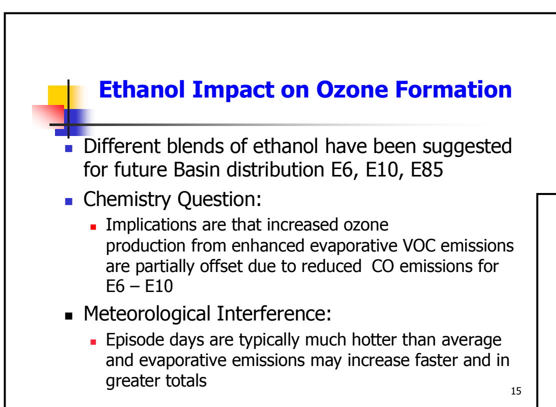
Issues that that could still be a problem for the SCAQMD are:

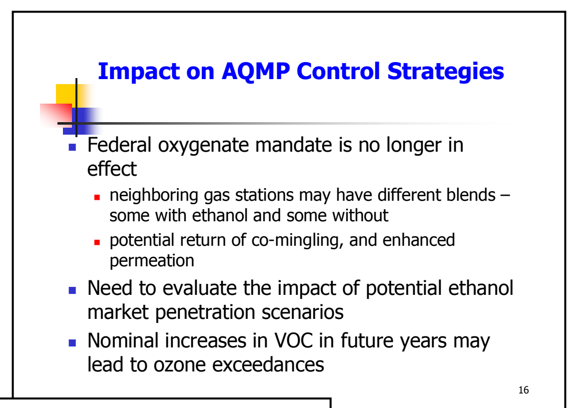
- If retailers are allowed to sell RFG with or without ethanol then commingling emissions could again be a larger contributor to HC emissions in the basin
- Even nominal increases in permeation emissions from new technology vehicles could result in not being able to meet standards due to the relative low carrying capacity associated with the 8-hr standard

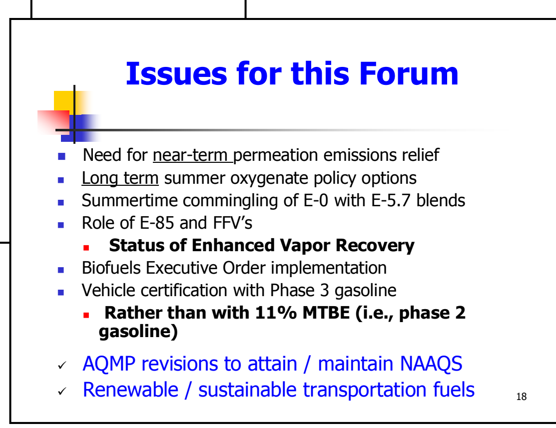
Gary Witten presented an argument that CO reductions associated with ethanol content should offset ozone formation associated with permeation emissions. He also discussed issues in ARB's current predictive model. The following provides some highlights:

- Statistical handling of "tech 4" vehicles did not provide the best correlation of NO_x with ethanol content and ARB is currently evaluating alternative correlation techniques
- CO emissions effects on ozone are currently underestimated by the predictive model due to low estimates of CO reductions and high ratio of CO/HC reactivity

If true the first factor would allow higher blends of ethanol—up to 10%. The second factor would suggest that permeation emissions will not affect ozone as much as one might expect based on HC emissions alone.





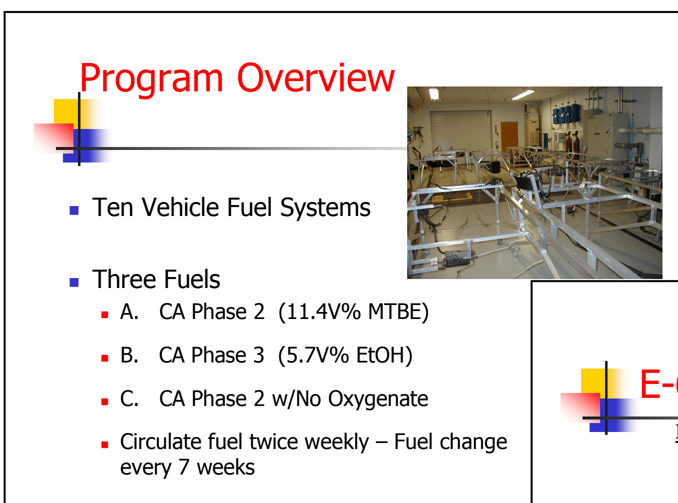


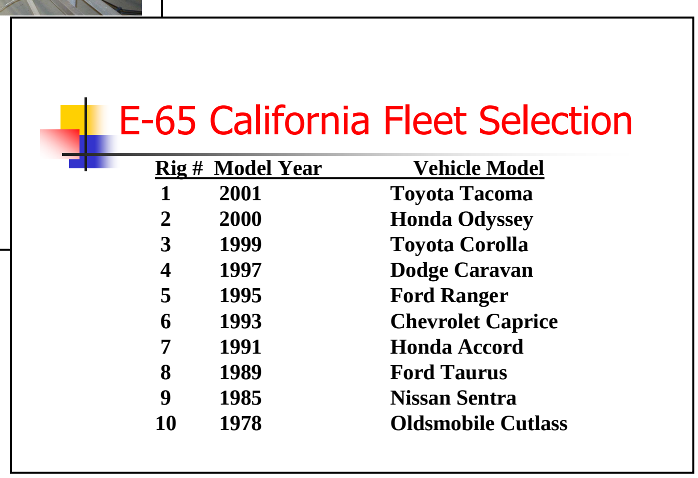
Witten argues that the current Predictive Model does not correctly account for CO adjustments (or offsets) for CO mass emissions or CO reactivity. This is an issue in the modeling. In fact as California transitioned from Phase 2 gasoline of 2 wt% oxygen using MTBE to a Phase 3 gasoline of 2 wt% oxygen using ethanol, CO emissions likely did not change whereas permeation emissions increased substantially. There is no CO mass emission "offset" unless the percentage of ethanol is changed. However, the PM is being adjusted to reflect the latest data on CO reactivity and how the CO emissions are accounted for over the entire blend range of ethanol content.

ARB confirmed that through the predictive model process they are evaluating alternative statistical methods for correlating the ethanol blend data and that they are also looking at the CO offset but do not believe they will conclude that CO emissions will completely offset the impact of permeation emissions on ozone.

2.2 Permeation Emissions

Harold Haskew of Harold Haskew and Associates reviewed evaporative testing performed for the CRC (Project E-65) that showed substantial increases in permeation emissions from a representative California fleet sample of older and newer vehicles. This CRC sponsored study investigated evaporative emissions from 10 vehicles and for three different fuels: RFG with MTBE, RFG with ethanol, and RFG with no oxygenate. Mechanisms of evaporative emissions include: leaks, tank venting, and permeation. Emissions from leaks and tank venting are minimized on new vehicle designs. There are also vehicle operational modes that include modes like diurnals, hot soak, running losses, and refueling emissions. These modes were not included in the CRC E-65 project, but are affected by increased permeation emissions.





Rig #	Model Year	Vehicle Model
1	2001	Toyota Tacoma
2	2000	Honda Odyssey
3	1999	Toyota Corolla
4	1997	Dodge Caravan
5	1995	Ford Ranger
6	1993	Chevrolet Caprice
7	1991	Honda Accord
8	1989	Ford Taurus
9	1985	Nissan Sentra
10	1978	Oldsmobile Cutlass

Several major conclusions resulted from the E-65 study:

1. Permeation emissions are significant for ethanol RFG compared to MBTE or no oxygenated fuel. Rates as high as three times those of MBTE or no oxygenate were found for ethanol RFG.
2. Permeation emission rates take several weeks to stabilize.
3. Permeation rate doubles for each 10°C increase.
4. Non-ethanol composition of the emissions was higher for ethanol blends than for MTBE or no oxygenate.
5. New vehicles have much lower permeation emissions than older vehicles.

Figure 2 shows the results of the testing from the CRC E-65 project. These data show the increase in permeation emissions of ethanol compared to MTBE or gasoline without an oxygenate.

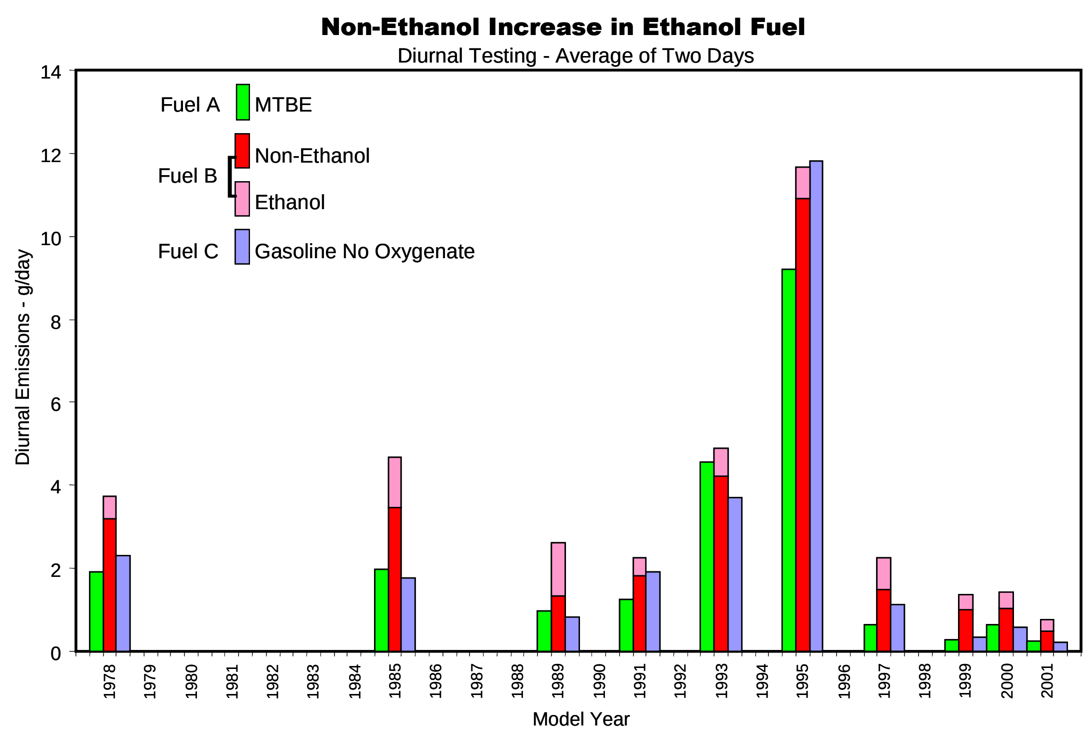


Figure 2. Permeation Emissions from CRC E-65 Project

An estimate of the amount of emissions associated with permeation emissions in the South Coast as well as California is shown in the Table 4. These estimates were provided by ARB in a November 3, 2005 draft analysis.[3] Estimates included on-road as well as off-road applications. Off-road estimates were made assuming similar

[3] ARB current estimates (June 30, 2006) for SCAG are 26 tpd and for State 77 tpd in 2005.

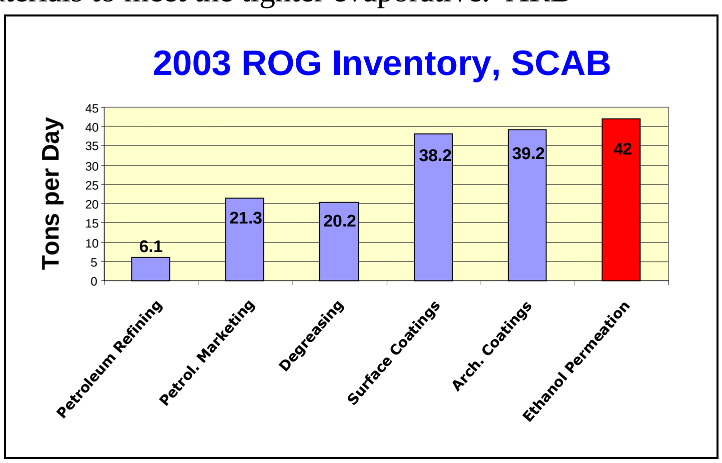
permeation emissions performance as with on-road vehicles. Also shown are the differences between a moderate temperature day and hot summer day. Total permeation emission increases of 24.9 tons per day (tpd) for the moderate day and 42 tpd for the hot summer day are significant compared to, for example, petroleum marketing emissions of 21.3 tpd or petroleum refining at 6.1 tpd (see inserted graphics next page)

Table 4. Estimate of Emissions Associated with Permeation Emissions in the South Coast and California

	Moderate Summer Day 83 °F		Hot Summer Day 97 °F	
	SCAB	Statewide	SCAB	Statewide
On-road	**17.5**	**49.2**	**29.5**	**82.9**
Off-road	**7.4**	**20.8**	**12.5**	**35.1**
Total	**24.9**	**70.0**	**42.0**	**118.0**

The representatives of the auto, oil, and ethanol industries all acknowledged that low level ethanol blends increase permeation emissions. A key question raised to Haskew related to the appropriateness of extrapolating the sample of 10 vehicles to 20 million plus light-duty vehicles in California. Obviously, more testing is needed, but compared to no data, the CRC E-65 study was a great improvement. Additional testing is planned to investigate actual evaporative emission mechanisms from in-use vehicles (CRC Project E-77) and to obtain more data on permeation emissions with newer vehicles and different fuel blends (CRC E-65.3).

Haskew found that permeation emissions for newer cars were lower than for older cars. The highest permeation emissions where found on a MY95 vehicle that used a plastic fuel tank. Haskew speculated that California's shift to 24-hour diurnal evaporative testing probably was one reason the newer cars performed better since auto manufacturers had to change materials to meet the tighter evaporative. ARB commented that although the newer cars are lower in permeation emissions these emissions may be small (but potentially significant) in the out years and will still need to be mitigated either through changes in the Predictive Model or other non-fuel strategies.



2.3 ARB's Predictive Model

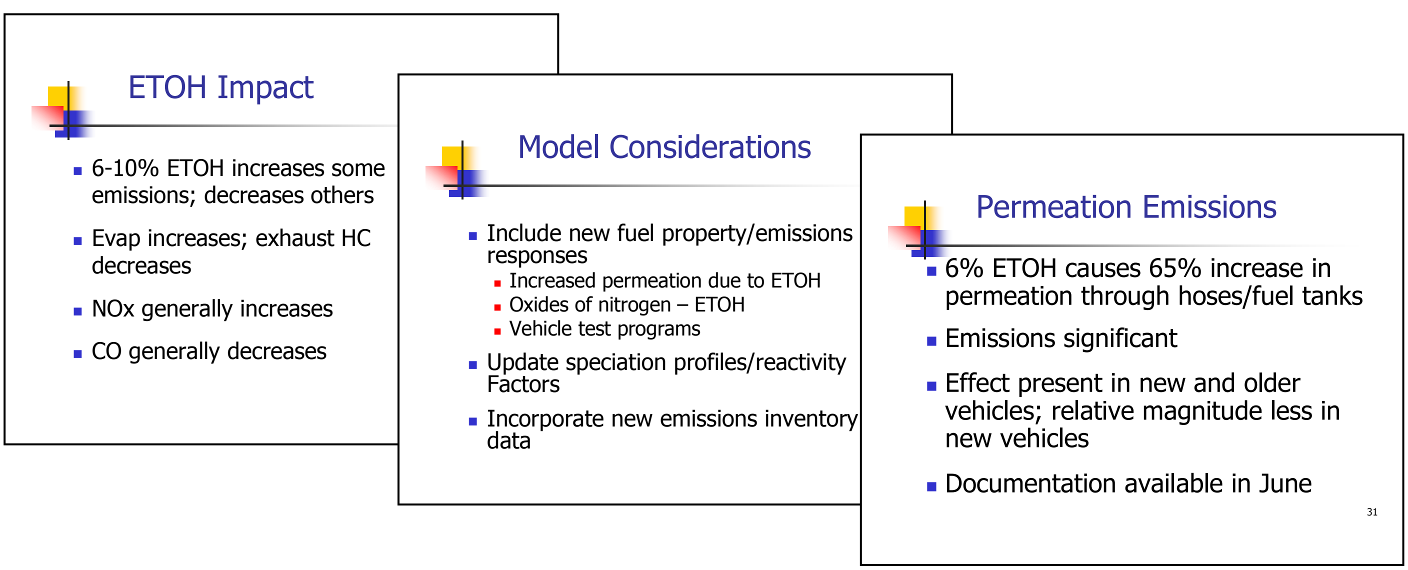
ARB's Predictive Model is important in that it provides flexibility to refiners to meet the current CaRFG3 standards. The current model is somewhat out dated and needs to be updated with more recent vehicle emissions data. Bob Fletcher of ARB provided an overview of ARB's current goals on the predictive model update. ARB's goals are to:

- Update the model with the latest data
- Mitigate the emission increases associated with ethanol blends
- Enable continued use of ethanol at levels needed to comply with the 2005 Energy Act
- Explore opportunities for increased ethanol use
- Explore wide range of mitigation strategies
  - Greater use outside of smog season
  - Use non-fuel measures to mitigate effects

The Predictive Model provides estimates of hydrocarbon, oxides of nitrogen, and potency-weighted toxics as a function of fuel composition / properties. Hydrocarbon emissions include evaporative, exhaust, and reactivity-weighted adjustments. They are including new fuel property and/or emission responses for permeation emissions (which were previously not included), oxides of nitrogen, and vehicle test programs. They are also updating speciation profiles and reactivity factors as well as incorporating new emission inventory data through updates to EMFAC which is currently being updated for the SIP.

ARB has an aggressive schedule in place to update the predictive model as shown below:

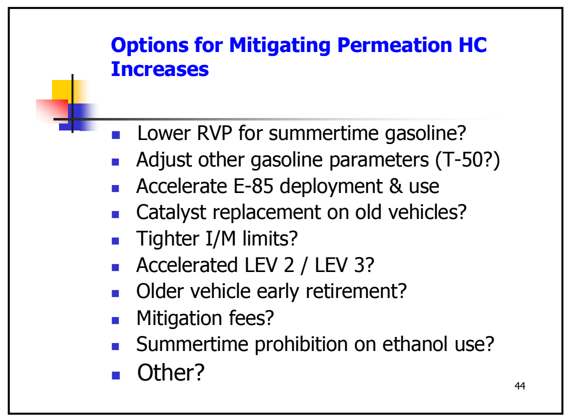
• Statistical evaluation	June 2006
• Mitigation strategies	July 2006
• Initiate Peer Review	August 2006
• Staff Report	October 2006 (was September originally)
• Board Hearing	December 2006 (was October originally)



Although this is an ambitious schedule, ARB understands the importance of getting the results as accurate as possible and will delay the process if necessary. This point was also stressed by the oil, auto, and ethanol stakeholders present at the meeting.

ARB's expectations for low level blends include the following. The refining and distribution system is in place to manage ethanol. Refiners will likely continue to use ethanol to ensure supplies. The challenge is to maximize flexibility to use ethanol while preserving air quality benefits of clean fuels. In this light, RFG blends of 10% ethanol may be more difficult to mitigate than those of 5.7% ethanol currently used in CaRFG3.

State law requires that control measures designed to reduce targeted emissions do not increase other emissions and therefore reduce the impact of the control measure. In the case of RFG regulations, the objective of these regulations was to reformulate gasoline to enable lower emissions of HC, NO_x, and CO as well as toxics compared to conventional gasoline. Increasing permeation emissions associated with ethanol RFG fails the state requirement and therefore by law ARB is required to mitigate these emissions. The most straightforward strategy may be to incorporate the increase in permeation emissions in the Predictive Model. Compliant E5.7 would then meet the CaRFG3 standards and would not have an increase in HC, NO_x, CO or toxic emissions. However, this may not be technically or economically feasible and ARB will have to look for other non-fuel strategies to mitigate the increased emissions associated with ethanol RFG permeation.



There was some question from WSPA and the Alliance of Auto Manufactures on ARB's authority to implement non-fuel strategies. ARB believes they have this authority and assured the participants that they would work with affected industries and would also make sure any strategies are within their legal authority.

As discussed above, ARB plans to update the Predictive Model with newer data. This will include not only the new permeation emissions data but also data on the exhaust emissions performance of low level ethanol blends. The next section discusses these data.

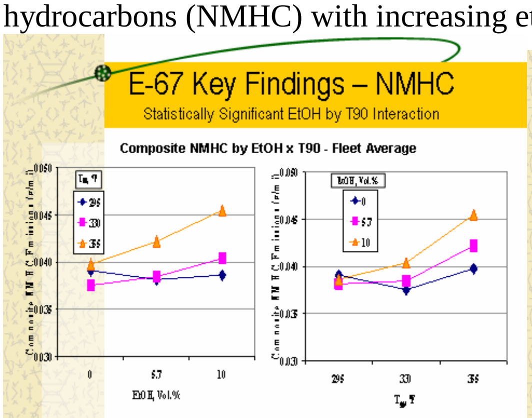
2.4 CRC Low Level Blend Results

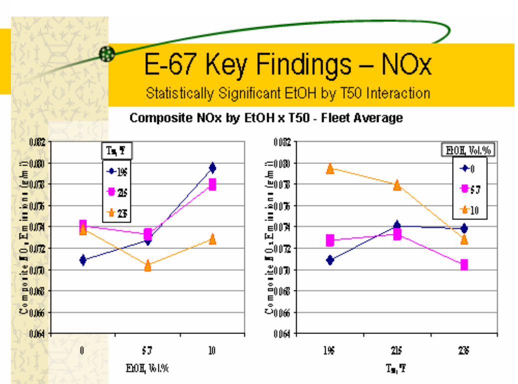
CRC contracted with the University of California Riverside to perform a comprehensive fuel-vehicle emission assessment of low level ethanol blends (CRC Project E-67). Full details of the testing scope and test results are provided in Tom Durbin's presentation located on the SCAQMD website.[4] This section provides highlights and any issues that were noted by meeting participants.

The objective of the E-67 project was to expand the database of information available on the impacts of gasoline volatility parameters and ethanol content on exhaust emissions from recent model light-duty vehicles. The scope of the testing included 12 vehicles and 12 different fuels. The vehicle set was composed of California certified model year (MY) 2001, 2002, and 2003 vehicles. Certification levels included mostly LEV and ULEV with one SULEV. Fuels included variations on ethanol (0%, 5.7%, and 10%), 90% distillation temperature, 50% distillation temperature, T_{50} (195 ^{o}F, 215 ^{o}F, and 235 ^{o}F) or T_{90} (295^{o}F, 330 ^{o}F, and 355 ^{o}F). The test protocol included measuring exhaust emissions over the standard FTP. The order of fuel-vehicle testing was randomized and each fuel-vehicle combination was tested at least twice. For several fuel-vehicle combinations the HC exhaust was speciated to provide additional information on toxic emissions. The test results were statistically analyzed using standard software.

The key findings of this study are summarized in Table 5. Past testing and the current Predictive Model shows/gives lower HC and CO exhaust emissions with increasing ethanol content. NO_x emissions increase going from 5.7% to 10%.

The results of the E-67 project were more complicated as a function of the ethanol content of the fuel and the gasoline distillation properties (see Table 5). Unlike previous testing in older model vehicles the E-67 results show an increase in non-methane hydrocarbons (NMHC) with increasing ethanol content at the mid and high T_{90} levels.





[4] http://www.aqmd.gov/tao/ConferencesWorkshops/06_EthanolWS/Ethanol_Forum_Agenda.htm

Table 5. Summary of CRC E-67 Test Results for Low Level Blends in LEV, ULEV, and SULEV Light Duty Vehicles

Key Findings: NMHC NMHC increased with increasing T50. The fleet-average percentage increases in NMHC in going from the low and mid-point level of T50 to the high T50 level were 36 and 25%, respectively. A significant interaction was found between ethanol and T90 NMHC increases with ethanol at mid- and high T90 NMHC increases with T90 at mid- and high ethanol levels
Key Findings: CO CO decreased with increasing T90. The percentage decreases in going from the low and mid-point level for T90 to the high T90 level were 24% and 7%, respectively. A statistically significant interaction was found between ethanol and T50 CO decreased when ethanol was increased from 0% and 5.7% CO was unchanged or increased when ethanol was 10% CO increased with T50 at 5.7% and 10% ethanol levels CO was unaffected when no ethanol was present
Key Findings: NOx A significant interaction was found between ethanol and T50 NOx increased with increasing ethanol at low level of T50 At mid-point level of T50, NOx was largely unaffected as ethanol was increased from the zero to the mid-point level, but increased as ethanol was increased to the high level. At the high level of T50, NOx is largely unaffected by ethanol Alternatively, NOx decreased with increasing T50 at the high level of ethanol, but was largely unaffected by T50 at the zero and mid-point levels of ethanol
Key Findings NMOG and Toxics NMOG: Increased by 14% when ethanol was increased from zero to the high level. Increased by 35% when T50 was increased from the low to the high level. Formaldehyde: Increased by 23% when T50 was increased from the low to the high level. Acetaldehyde: Increased by 73% when ethanol was increased from zero to the high level. Benzene: Increased by 18% when ethanol was increased from zero to the high level. Increased by 38% when T50 was increased from the low to the high level. 1,3-butadiene: Increased by 22% when ethanol was increased from zero to the high level. Increased by 56% when T50 was increased from the low to the high level.

CO emissions for these modern vehicles decreased with increasing T90, but showed mixed results with ethanol content and T50. For example, CO decreased from 0% to 5.7% ethanol and then was unchanged or increased at 10% ethanol depending on T50 temperatures. Similar results were seen for NO_x. NO_x mostly increased with increasing ethanol content at the low T50's and at the mid level T50 point NOx increased with ethanol content between 5.7 to 10%. At the high level of T50, NOx was largely unaffected by ethanol.

Interestingly, NMOG, acetaldehyde, benzene and 1,3 butadiene showed increases with increasing ethanol content. These trends follow the trend of increasing hydrocarbon concentrations with increasing ethanol content. However, all the speciated data were reported at the highest T90 which also had the highest HCs. These levels are high compared to what would be expected at lower T90 temperatures. The effects of ethanol and T50 on NMOG and toxics were only observed for the subset of fuels having the high level of T90. The results of this study do not permit any conclusions as to what effects ethanol and T50 might have had on NMOG or toxic emissions for fuels having low or mid-point T90 levels.

2.5 Summary

Table 6 summarizes the issues that were presented and discussed in the technical forum relative to low level blends of ethanol in gasoline. Permeation emissions from ethanol blends in current vehicles are significant and can continue to have negative effects on the state's air quality. At the same time more data are needed over a wider variety of vehicles and in larger numbers to assess the air quality impact. ARB is currently updating the predictive model with the newer permeation and exhaust emission data. The Predictive Model may not completely incorporate the impact of permeation emissions and additional air quality mitigation measures may therefore be required.

Future policy on low level ethanol blends needs to balance the air quality impacts, reduction in climate change emissions (greenhouse gases), and petroleum displacement. Vehicles can be designed to minimize permeation emissions as illustrated by the testing on the newest low emission vehicles as well as FFVs. Unfortunately, there is no retrofit for the fleet of older vehicles and these vehicles, which have high permeation emissions, will be used for many more years.

Table 6. Issues and Findings for Low Level Ethanol Blends in Reformulated Gasoline

Low Level Blend Issues	Findings
▪ Permeation	✓ Significant in near term and in out years: estimated on and off-road HC increase in SCAB: 26 tpd (2005) and 14 tpd (2020) ✓ Permeation emissions double for each $10^{o}C$ ✓ No known retrofit technology ✓ ARB will incorporate in Predictive Model ✓ Mitigation of on and off-road emissions may require more than fuel strategies
▪ Predictive Model Accuracy / Robustness	✓ Current data set is heavily skewed with old vehicle and fuels data ✓ New data on ULEV and SULEV show complicated interaction between gasoline volatility and ethanol ✓ Update should make sure science is right—model can have big effect on emissions as well as economic viability of reformulated gasoline ✓ 10% ethanol blends show an increase in NOx emissions
▪ Mitigation strategies	✓ ARB required by state law to ensure control measures do not increase emissions—e.g. the permeation emissions impact of the transition from Phase 2 to Phase 3 California gasoline must be mitigated. ✓ ARB will evaluate both fuel and non-fuel strategies to mitigate emission increases ✓ Predictive model could provide fuel strategy if resulting reformulated gasoline is economic ✓ Summertime zero ethanol policy is fuel strategy but would not be favored by refining or ethanol industries ✓ It's not clear that fuel offset requirements alone will be sufficient.
▪ CO / HC tradeoffs	✓ Ethanol industry suggests that HC increases are fully offset by CO reductions if CO reactivity is adjusted as proposed by the ethanol industry. ✓ ARB is updating its analysis and the predictive model but do not expect for CO reactivity to completely offset permeation increases
▪ Commingling	✓ Commingling of ethanol in non-ethanol blends recognized as resulting in higher RVP and potentially higher evaporative emissions and could have been partially responsible for SCAB's high ozone in 2003
▪ Certification test fuel	✓ Current gasoline certification based on MTBE (Phase 2) hence reason for permeation surprise ✓ Auto manufacturers view any change in certification as major ✓ PZEV certification requirements are currently a barrier to E-85 FFV certification, although efforts are underway by manufacturers to address this issue.
▪ Greenhouse Gas Benefits	✓ Corn-based ethanol offers 23% GHG benefits ✓ Cellulosic feedstocks offer 75-80% GHG benefits

3. E85 Ethanol Blends

Nearly all presenters discussed the benefits and potential issues of fuel ethanol (E85) fuel use in vehicles.

- CEC has advanced many recommendations in their "Integrated Energy Policy Reports" for E85 use in flexible fuel vehicles (FFVs); the Governor is also promoting the use of biofuels in transportation

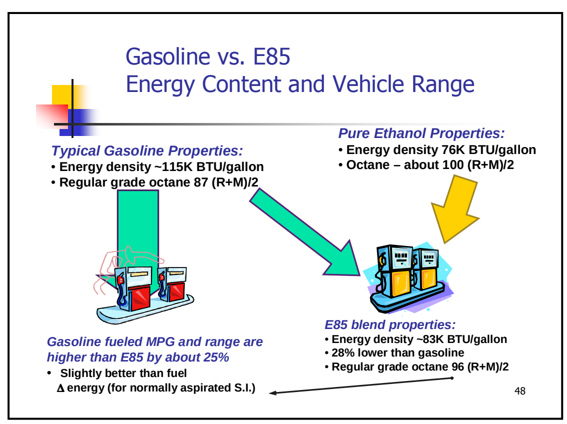
- ARB encourages the use of E85 in the current and future California fleet of FFVs. Strategy provides greater petroleum fuel displacement and greater greenhouse gas emission reductions with low criteria emissions typical of new cars

- Ethanol industry promotes low level blends and E85. The industry thinks the market will be rational and can have blend and E85 pricing.

- WSPA noted that one of their prime concerns is the reduced mileage of E-85 (20-30% decrease) due to a lower energy density, and whether consumers will see the value in the vehicle/fuel combination that will deliver a reduced range. They acknowledged that E85 will extend overall transportation fuel but they also point out E85 is not compatible with existing gasoline and diesel infrastructure. FFVs are still small percentage of vehicles and may be difficult to recover E85 station investment. Other issues of concern are limited data on FFV emissions, multimedia environmental impact, and misfueling and commingling.

- Auto Manufacturers are designing vehicles for E85 use (e.g., software, optical sensor, and changes in fuel-wetted materials). They need fuel specification for E85 which would include additives. Also cold climates may require blends as low as E70.

- Air quality agencies (SCAQMD) are concerned about certification of current FFVs and newer FFVs meeting PZEV levels. E85 has much lower volatility than low level blends which reduces evaporative emissions of HC and toxics. ASTM and ARB are both working on specifications to address the volatility requirements for E-85. Need more in-use and other test data on tailpipe emission performance of current and future FFVs.



Of the above issues, this section focuses on emissions from FFVs and the business case for an E85 infrastructure. Current and future FFVs should at least be comparable to gasoline vehicle emissions for an E85 strategy to make sense in California. FFVs partially solve the "chicken and egg" problem with alternative fuels since FFVs can use gasoline until the infrastructure develops. However, an E85 fueling infrastructure has not developed yet in California. However, the business case may be more attractive as E-85 prices decline with growing supplies and the Phase II vapor control issue is addressed.

3.1 FFV Emissions

Little work has been done on a fuel specification for E85 since the mid 1990s. Vehicle manufacturers need to have some assurances that E85 and variants will meet fuel specifications to ensure proper vehicle and emissions performance over full vehicle life. It may not be sufficient to assume that the current additives and specifications for gasoline with low level blends will also work for higher level blends.

FFVs have both evaporative and tailpipe emissions. Like non-FFVs the evaporative emissions include permeation, leaks, and tank venting. Unlike non-FFVs, FFVs are designed and tested on E10 and E85. FFV fuel tank and other fuel system materials have been changed to meet evaporative standards.

Newer gasoline vehicles and FFVs have been designed to comply with "enhanced" evaporative emission regulations which began to take effect in the mid 1990s. The subsequent use of improved fuel system materials has greatly reduced total evaporative emissions and permeation evaporative emissions. New PZEV "zero" evaporative emission requirements are expected to reduce these emissions to even lower levels. Some experts believe that permeation emissions in the out years may not be significant. As noted above, recently released CRC E-65-3 study data suggest that FFV are equally susceptible to permeation increase with low level (E10) blend compared to gasoline not containing ethanol. Lower permeation emissions on E85 occur due to the lower permeability of this fuel compared to lower level ethanol blends or E0.

However, aside from certification testing on E85 there has been little testing performed on in-use vehicles over the standard FTP and little or no testing over a range of ethanol blends possible in actual use (FFVs can use any mixture of ethanol and gasoline from 0% ethanol to 85% ethanol). Since there is so little use of E85 in California FFVs, it is difficult to determine what a typical consumer's response would be. If ethanol was available, would consumers mostly use E85 and occasionally fill with gasoline when E85 not available? Would they base their selection on whether E85 or gasoline was cheaper (and would this be done on an energy basis)? Likely, there are a variety of responses from consumers and this will result in a range of ethanol gasoline mixtures being used. In-use testing, therefore, should include a full range or potential mixtures, and these tests should include evaporative and FTP testing.

In his presentation, Mike Ingham (Chevron) outlined testing that is being considered by CRC to answer some of these questions. CRC is currently funding a 2006 Hot Fuel Handling Program that will test 12 fuels (E0, E5.7, E10, and E20 at three volatility levels) and 25 vehicles (20 late MY and five 10 year old vehicles). CRC is also developing a proposal to test materials compatibility and is attempting to get cosponsors from motorcycle, small engine, and marine industries. CRC is considering the following E85 studies:

- Commercial E85 fuel quality survey
- Tailpipe emissions study of FFVs as a function of ethanol concentration (E0-E85)
- Permeation study of FFVs (E0-E??)
- Cold-start and driveaway performance study of FFVs as a function of E85 composition

These studies will provide data on the emission performance of vehicles using higher blends of ethanol in gasoline.

Another issue that gets raised is whether the auto manufacturers will certify FFVs for California meeting the tighter PZEV emissions standards in the 2007 and later model year while also complying with the existing EPA testing protocol requirements which are unique to FFVs. Ellen Shapiro (Alliance of Automobile Manufacturers) indicated that the automakers are prepared to manufacture vehicles meeting the standards before them.

3.2 Infrastructure Business Case

Widespread use of E85 will not occur until the fueling infrastructure develops. As pointed out in the presentations by Peter Ward (CEC) there are currently about 250,000 FFVs in California but only one retail station and two private stations dispensing E85. Thus, most of these vehicles are using E5.7 RFG.

What are the barriers to an E85 infrastructure? This was explored in several presentations and in the roundtable discussion. One question that comes up is: Why would the consumer want to purchase E85 even if it was available? There is very little published market research on this issue, but presumably lower price compared to gasoline would be one attractive attribute. Several years of experience with E-85 marketing in Minnesota has indicated that E-85 priced at 15-30% below the price of unleaded regular gasoline per gallon would provide an attractive value proposition to consumers.

Although E85 is a liquid fuel like gasoline, infrastructure changes are necessary to handle ethanol’s unique properties. Changes may be required in tanks, piping, and dispensing equipment. Also, additional retail space may be needed to accommodate E85 dispensers. The investment could be expensive up to $200,000 per station if all ethanol compatible equipment is needed. Modification of an individual dispenser could cost as little as $5,000, assuming all underground piping and tank hardware is E-85 compatible.

Outside of California, there about 1,000 E85 stations and partnerships are developing with retailers and the ethanol industry. In California ARB is working with GM, Chevron, and Pacific Ethanol to develop an E85 demonstration program. CalTrans' fleet will use E85 at two locations for about one year. Vehicles have been acquired and infrastructure is being established.

Another discussed issue involved the supply and current price of ethanol. Ethanol spot market prices according to Gary Herwick (Transportation Fuels Consulting) are in the $4 per gallon range. This is reflective of a tight supply market and Gary projects this to ease as new supply is brought on-line. Ethanol contract prices are in the $2 to $3 per gallon range and typically comparable to unleaded regular gasoline. Nevertheless, these prices are reflective of ethanol being valued and sold into the gasoline blend market where it competes with other octane enhancers or other blend components needed to meet RFG requirements. For the E85 market, ethanol or E85 would have to compete with gasoline on an energy basis. E85 has a low heating value of about 72% of CaRFG3. Thus, on an energy basis E85 would need to be priced at about 72% of gasoline. Herwick suggested that in a rational market this would be the case even if ethanol continues to be used in the low level blend market. However, this was not the experience with methanol and MTBE in California.

Although some of the issues regarding the business case for E85 were discussed, there was no consensus among the stakeholders and there seemed to be more questions remaining than answers. Questions needing answers from our perspective are:

- What's the value proposition for the consumer? Will ethanol be priced competitively with gasoline?
- Who is going to make the retail station investment? And how will the stations be phased in over time to match vehicle purchases?
- How will station owners recover their investment?
- How will misfueling be prevented?

3.3 Summary E85

E85 provides potentially larger benefits for improving air quality, lowering greenhouse gas emissions, and petroleum displacement. However, these benefits will not be achieved without a concerted effort by industry and state agencies. Automakers will have to provide FFVs with advanced emissions and engine technologies. Oil companies and retail fueling stations will have to develop viable business approaches to invest in E85 infrastructure and then to attract customers to purchase E85 in order to recovery their investment. This will require a coordinated effort from the automakers, the retail stations owners, and state agencies.

A lot more testing is needed to ensure the emissions benefits of FFVs. Testing should include not only that done for certification, but also testing of in-use vehicles to verify emissions performance over the life of the vehicle on E-85 and the full range of fuels. Additional work is also needed on the ozone reactivity of the exhaust from FFVs.

Previous work has shown that ethanol emissions are less reactive, and thus have the potential to provide additional air quality benefits.

Ethanol pricing will continue to be an issue with the current tight market. However, as newer production comes on line, it is anticipated that ethanol prices will more reflect the cost of the product. This will be necessary for ethanol (as E85) to compete with gasoline.

Commingling emissions are still a concern with current and future FFV designs. It is clear that most users will at sometime in their ownership fuel with only gasoline or E85. This will result in fuel mixtures less than E85 and potentially result in higher permeation/evaporative emissions as well as higher exhaust emissions or at least higher reactive exhaust mixtures. The ethanol blend level cross-over point and the reactivity implications need to be more fully studied. More emission testing data are needed to investigate possible commingling issues.

Finally, work is needed to develop cellulosic pathways for ethanol production. Cellulosic ethanol provides the greatest climate change emissions benefit.

Table 7. Issues and Findings for E85 Transportation Fuels

E85 (Fuel Ethanol)	Findings
▪ E85 Infrastructure	✓ Only 1 retail station in California ✓ Consumer value proposition for using E85 ✓ Business case to install infrastructure ✓ Cost of infrastructure and transition throughout state ✓ Early joint ventures between oil companies and ethanol producers to establish fueling stations underway ✓ Need enhanced vapor recovery systems for ethanol ✓ Since a majority of FFV's on the road will have On-board Vapor Recovery, the need for Stage II vapor recovery is being assessed
▪ Prices	✓ E85 is a harder business case than low level blends under current commercial market economics ✓ Incentives likely to be needed in short and medium term
▪ Supply Availability	✓ Current U.S. ethanol production stands at 4 billion gallons ✓ Industry expects to exceed the 2012 RFS goal of 7.5 billion gallons within the next 2 years; unconfirmed estimates may be in the range of 15-20 billion gallons, although further assessment of this issue is needed. ✓ Uncertainty exists on the upper limit above which food, soil and water resources severely affected by diversion of corn to ethanol
▪ Availability of FFVs	✓ GM is the only 2006 manufacturer in California ✓ Will OEMs produced advanced FFVs meeting PZEV standards
▪ Emission Benefits of FFVs	✓ Essentially no in-use testing data for FFVs ✓ Catalyst durability for consistent aldehyde control needs in-use confirmation ✓ MIR reactivity studies somewhat outdated ✓ Need for testing of latest model FFVs ✓ One permeation test point expected under CRC project E-65-3
▪ FFV use of commingled fuel	✓ Current FFV designs are certified to comply with exhaust and evaporative requirements on E-85 and E-10. ✓ In the early transition years (e.g., through 2020) however, the lack of widespread E85 station availability will likely result in some commingling of gasoline and E85 reducing the maximum benefit of E85 ✓ The role of older FFVs may remain an issue during this transition period, as new technology vehicles which meet near-zero and PZEV standards are phased into the fleet.
▪ Permeation emissions	✓ Permeation emissions are expected to decline to very low levels as vehicles with newer evaporative controls come to dominate the fleet. [5]
▪ Climate Change Emissions	✓ Larger potential GHG emission benefits than low level blends ✓ Corn-ethanol pathway provide 23% GHG benefits ✓ Cellulosic ethanol pathway provide 75-80% GHG benefits ✓ California pursuing biofuels production and use

[5] Data on one FFV shows an increase in permeation emissions when tested on E10, compared to E0. The latest CRC report (E-65-3) shows that E85 permeation was half that of E0. It is likely, therefore, that FFVs will show an increase in permeation with low level ethanol fuels compared to E0 or MTBE fuels.

4. Petroleum Displacement and Climate Change

Ethanol used in CaRFG3 is currently displacing 900 million gallons of gasoline as a result of California's ban on MTBE and the Federal Clean Air Act [6] mandating use of an oxygenate. Ethanol is being produced from corn and imported to California from the Midwest. Relative to the use of other alternative fuels in displacing gasoline or diesel fuels, ethanol has been very successful. The questions that come up in evaluating a continuing ethanol strategy include how can ethanol help (1) achieve California's renewable energy goals, and (2) reduce California's impact on climate change while supplying a significant portion of California's fuel demand.

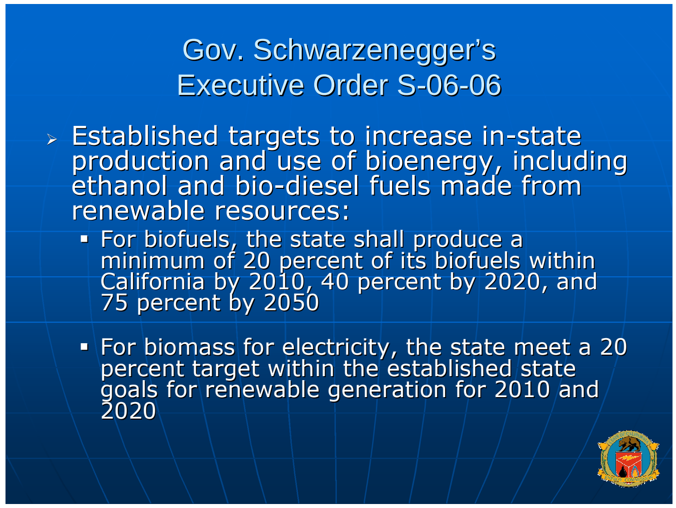
4.1 Meeting California Renewable Goals

Peter Ward (CEC) and Gary Herwick (Transportation Fuels Consulting, representing the ethanol industry) both provided overviews of goals and policies being recommended or adopted for renewables in California and throughout the U.S. Both suggested that ethanol could play a large role in meeting such goals and policies.

In California, the legislature, the Governor, and state agencies have developed legislation, executive orders, and recommendations for the increased use of alternative fuels. CEC in its Integrated Energy Policy Reports (IEPR) has recommended expansion of E85 use as well as increasing ethanol content to 10% in low level blends. CEC also adopted a goal of 20% alternative fuels use by 2020 and ethanol is expected to play a significant role in meeting this goal. The state has also been putting together a bioenergy action plan that includes working group report to governor, governor issuing Executive Order S-06-06, working group detailed action plan for California, and CEC adopting alternative fuels report in December 2006.

Executive Order S-06-06 targets to increase in-state production and use of bioenergy, including ethanol and biodiesel fuels made from renewable resources. For biofuels the goals are to produce 20% in-state by 2010, 40% by 2020, and 75% by 2050. The EO also requires the Resources Agency and CEC to coordinate work among state agencies to promote the use of biomass resources.

[6] Clean Air Act 1990 Amendments, Section 110 (k) (2) Oxygen content. The 2005 Energy Policy Act eliminated the oxygen requirement in federal RFG, and was replaced with the federal Renewable Fuel Standard.



Assembly Bill 1007 (Pavely) restates the goal to increase alternative fuel use to 20% by 2020 and requires CEC to develop an alternative fuels plan by June 2007.

On the federal side, the Energy Policy Act of 2005 sets a renewable fuels standard (RFS) of 7.5 billion gallons of ethanol use in the U.S. by 2012 and also eliminates the oxygenate mandate requirement in the Clean Air Amendments of 1990. There is a lot of flexibility in the RFS; California refiner allocation in 2011 is about 850 million gallons of ethanol, about what was used in 2005.

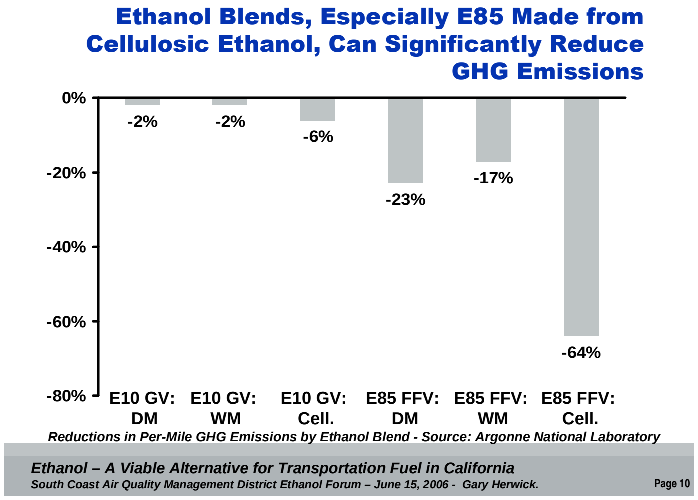
4.2 Ethanol as Climate Change Strategy

Gary Herwick showed results of the Argonne National Laboratory study on well-to wheels analysis of greenhouse gas emissions associated with various fuel and vehicle technology combinations. The results of this study are similar to work performed in California by ARB and others. A recent California study[7] estimates the corn-to-ethanol benefit at 18% with a range of uncertainty from -36% to +29%. ARB's estimate was a 23% benefit for corn-based ethanol.[8] Argonne's results, however, show considerably more benefit for cellulosic ethanol. In their analyses they show benefits of 64%. Farrell, et. al., also show larger benefits (88%) for cellulosic ethanol compared to gasoline.[9]

[7] Farrell, Alexander E. et al, "Ethanol Can Contribute to Energy and Environmental Goals," Science, Vol 311, pg 506, January 27, 2006.

[8] ARB, "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.

[9] One presenter pointed out that while cellulosic ethanol is "5 years away", corn-based ethanol does offer immediate GHG reduction potential.



Stakeholders agreed that all sources of ethanol, including corn-based production, will be needed to contribute to the on-going commercialization of fuel ethanol. The state agencies want to promote wider ethanol production using biomass and waste products to maximize greenhouse gas reductions and California production.

5. Concluding Remarks

The presenters at the ethanol technical forum and roundtable discussion were asked to consider several questions relative to low level blends of ethanol and gasoline and fuel ethanol or E85. These questions were provided in the introduction (Section 1) and are repeated here with our best assessment of what the consensus was at the meeting.

Low-Level Blends

1) *What options exist to fully mitigate the 42 tons per day of extra VOC emissions in the South Coast Air Basin resulting from the permeation emissions associated with low level blends?*

   ARB's current estimate is 26 tpd in 2005. ARB will first evaluate fuel strategies that are possible. This will be done through the Predictive Model update and also the current process to update EMFAC and the OFFROAD models for the up coming 8-hr ozone SIP analyses.

   The refining industry wants ARB to do the science right in correlating all the new data. They will live with the consequences of the modeling (that describes as best as possible what is actually occurring in use).

   If fuel options do not fully mitigate the increased permeation emissions, ARB will also evaluate non-fuel strategies. These strategies were not discussed. WSPA and the Alliance questioned ARB's legal authority to implement non-fuel strategies. They also suggested working closely with ARB on these issues.

2) *What would be the gasoline supply impact of eliminating the use of ethanol during summer months?*

   Summer months are the biggest driving months of the year and thus the months of highest demand for gasoline. Eliminating ethanol to the fuel supply would aggravate the supply of gasoline during these periods and could disrupt the overall transportation fuels market. ARB indicated that they are not inclined to ban the use of ethanol during the summer months.

   That said, the refining industry seem to respond that they could accommodate ethanol or not depending on the outcome of the Predictive Model. However, the current system is optimized for ethanol. Refiners would have to make up octane, dilution, and other ethanol attributes in reformulated gasoline. The impacts on costs and RFG production are unknown at this time.

   Another issue is the Federal RFS (Renewable Fuels Standard) which requires multi-billion gallon renewables nationwide. If California drops out, this will substantially reduce ethanol demand, and this would considerably reduce system flexibility and could lead to more supply disruptions and price volatility.

3) *What research priorities do you see relative to low-level ethanol blends and for E85?*
   a) *For example, what commingling scenarios need better characterization?*
   b) *What are the prospects for demonstration and commercialization of optimized FFVs with plug-in hybrid capacity, such as the Saab 9-3 plug-in hybrid E100 prototype?*

   All participants agreed that more data are needed. This ranged from more evaporative emissions testing to more testing of FFVs. The amount of data obtained in the past Auto-Oil testing far outweighs the current testing data. CRC is undertaking several emission testing programs that will help fill in some of the data voids. Examples of programs on-going or planned are:
   - CRC E-77
   - CRC E-65.3
   - CRC Hot Fuel Handling Program
   - CRC proposed materials compatibility
   - CRC proposed commercial E85 fuel quality study
   - CRC proposed FFV tailpipe emissions study (E0-E85 fuels)
   - CRC proposed FFV permeation study (E0 and other levels of ethanol—to be defined)
   - CRC proposed cold-start and driveaway performance study with different E85 compositions

4) *Assuming the Predictive Model does not fully offset the permeation emissions associated with E-5.7 use due to permeation, what Air Quality Management Plan strategies should be considered to address this portion of the "black box" of needed emission reductions to attain federal and state air quality standards for both ozone and fine particulate?*

   Not addressed but the implication is that ARB will first consider fuel strategies presumably as part of the Predictive Model and if needed will then explore non-fuel strategies to mitigate the impact.

Fuel Ethanol (E85)

5) *What can be done to expedite the development and use of Enhance Vapor Recovery systems for E85?*

   Phase II vapor recovery issues are being studied by ARB.

6) *What policies should be encouraged regarding the use of Flexible Fuel Vehicles during the early stages of E85 station deployment?*

This transitional issue was not discussed, but there was considerable discussion on the business case for building an E85 fueling infrastructure. Barriers today include:

- Availability and cost of station equipment: storage tanks, piping, dispensers
- Ethanol pricing—will not compete with gasoline at current prices
- Consumers' reasons for buying E85 especially when attributes of E85 are less than gasoline, e.g. less driving range or less accessible fueling stations
- Liabilities associated with misfueling