

**Potential Maryland Air Emission Impacts of a Ban on MTBE in the  
Reformulated Gasoline Program**

October 18, 2005

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## 1.0 Summary

The State of Maryland has considered legislation that would ban the use of MTBE (methyl tertiary butyl ether) in the gasoline. This study examines the possible impacts on air emissions if MTBE use were to be discontinued. Since the recently passed Energy Policy Act of 2005 will remove the oxygen standard in the reformulated gasoline (RFG) program in the Spring of 2006, the Maryland gasoline marketplace might have a choice of using either an RFG with 10% ethanol or non-oxygenated RFG (or a market mix of both). Therefore, both replacement RFG options are considered in the air emission analysis in this study.

The results from this study show that using 10% ethanol will “increase” total ozone precursors (VOC + NO<sub>x</sub>) by as much as 15.8 tons during an ozone exceedance day. This increase is equivalent to about a 7 percent increase in VOC and NO<sub>x</sub> emissions from the on-road gasoline motor vehicle fleet. The results also show that switching to a non-oxygenated RFG will increase total VOC +NO<sub>x</sub> emissions by 7.0 tons during an ozone exceedance day which is equivalent to about a 3.2 percent increase from the on-road gasoline motor fleet. The emissions total for non-oxygenated gasoline does not include the large increase in CO emissions (325 tons per day), which is also a weak ozone precursor, that might be equivalent to increasing VOCs by another 7.2 tons per day.

Since Maryland continues to experience ozone exceedances under the new tighter federal ozone standards, the increase in air emissions from switching to either an ethanol-blended or a non-oxygenated RFG will likely need to be offset with additional emissions controls and their related costs. There is also a risk that ozone levels might increase by more than the percentage increases in the tons of the ozone precursors since the atmospheric VOC reactivity of any replacement for MTBE in gasoline will be much higher. Although EPA’s RFG complex model projects that switching from MTBE to these other fuel formulations would also increase localized air toxics emissions from the vehicle fleet by 6 to 14 percent, the absolute total increase in air toxics for Maryland is not estimated in this study due to insufficient information for air toxic emissions from gasoline related off-road equipment sources.

This analytical comparison study uses the latest known science for estimating the fuel composition effects on gasoline related emissions from both mobile sources (on-road gasoline motor vehicle fleet) and off-road sources (small gasoline engines). These enhancements in estimating emissions are currently not reflected in the EPA emission models used by states for predicting VOC and NO<sub>x</sub> emissions in Ozone SIPs (state implementation plans). The inclusion of off-road engine sources in this study is important since they represent a larger share of gasoline related emissions in the air basin emissions inventory than those from on-road vehicles. The most significant improvement in estimating emissions is the relatively recent knowledge that using ethanol in gasoline will significantly increase VOC permeation emissions through the vehicle plastics and elastomers in contact with the fuel by about 65 percent or more when compared to an MTBE fuel blend. This increase in permeation emissions affects evaporative emissions from on-road vehicles, off-road equipment and off-road vehicles, and portable gasoline containers. In addition, using 10% ethanol will increase the oxygen content by about 60 percent in the gasoline which then contributes to about a 4.5 percent increase in NO<sub>x</sub> emission from on-road vehicles. Because of these recent improvements in estimating emissions, this

analysis shows that switching from MTBE to either a 10% ethanol blend RFG or a no oxygenate RFG will result in a significant increase in ozone precursors into Maryland's air basin during a potential ozone episode day.

## 2.0 Introduction

Maryland is required to use federal Reformulated Gasoline, or RFG, which is a cleaner burning gasoline formulation that reduces pollutants from vehicles which form ozone, or ozone “precursors” (volatile organic compounds, or VOC, exhaust oxides of nitrogen, or NO<sub>x</sub>, and also exhaust carbon monoxide, or CO - a weak ozone precursor). Relative to a 1990 baseline, RFG reduces total vehicle VOCs by about 29%, NO<sub>x</sub> by about 7% and air toxics by about 32%. Until the recent Energy Policy Act of 2005 was passed, the law required that this federal RFG must contain an oxygen containing compound like MTBE or ethanol that adds at least 2 weight percent oxygen up to 3.5 weight percent. However, after the passage of the recent Energy Policy Act, the law no longer requires that RFG contain oxygen beginning in May of 2006. However, the percent reductions in VOCs and NO<sub>x</sub> of RFG at the local regional level still apply, whether the RFG contains oxygen or not. Since air toxic reductions targets in RFG are a national average requirement for individual refiners, local air toxics can increase without the use of MTBE.

Besides reducing emissions from on-road vehicles, the addition of oxygen in RFG is the only fuel property change that also reduces the exhaust VOC and CO emissions from the less sophisticated off-road gasoline engines. The inclusion of emission effects on off-road engine sources in this study is important since they now represent a larger share of the gasoline related emission inventory than emissions from on-road vehicles. The current RFG contains about 11 volume percent MTBE (2 % oxygen), which is a very clean burning, high octane, and easy-to-use oxygenate that has blended in gasoline since 1979. However, the state legislation requires the state to determine the impact of not using MTBE. The likely result would be a gasoline that either contains 10 volume % ethanol, or no oxygenate, or both. The choice of which gasoline to supply is a decision of the gasoline marketers based on feasibility and economics.

Many policy makers are under the false impression that all oxygen-containing compounds used in gasoline have about the same overall emissions impact. Except for air toxics, even the EPA emission models for both on-road and off-road vehicles do not differentiate between using ethanol or MTBE in RFG since these models were developed with an oxygenate-neutral policy where all oxygen in the fuel is assumed to have the same effectiveness in reducing exhaust emissions, and that emissions are assumed to change only linearly (or proportional) with oxygen concentration. Recent data and analysis from testing programs, however, show that there are significantly higher emission differences associated with the use of ethanol. Ethanol can increase NO<sub>x</sub> emissions from on-road vehicles at the higher oxygen levels, and ethanol also increases “permeation” VOC emissions from fuel system components (plastics and elastomers) in on-road vehicles, off-road vehicles, and portable gasoline containers. MTBE, however, does not increase NO<sub>x</sub> or VOC permeation emissions relative to a non-oxygenated gasoline. The oxygen in both compounds reduces exhaust carbon monoxide (CO) emissions which is a weak ozone precursor.

This study evaluates the overall air emissions impact of a switching RFG from 11 % MTBE to either 10 % ethanol, or no oxygenate in Maryland. The study uses recent testing data on ethanol permeation effects conducted by the Coordinating Research Council, a research group

funded by the automobile and oil companies. It also uses test data and analyses of the effects of ethanol on NOx emissions developed by the California Air Resources Board.

This report is organized into the following sections:

- Background
- Methodology Used in the Study
- Maryland Gasoline Characteristics
- Permeation VOC Emissions
- Atmospheric Reactivity of VOCs
- Results
- Discussion

There are three additional sections:

- References
- Appendix 1: Analysis of Oxygen Effects of Two-Stroke Engines
- Appendix 2: Background on Air Improvement Resource, Inc.

### 3.0 Background

Gasoline related emission inventories are made up of a combination of exhaust emissions and evaporative emissions. While exhaust emissions are made up of unburned hydrocarbon emissions (VOCs), NO<sub>x</sub>, CO, and air toxics, the evaporative emissions are made up only of VOCs since they represent those gasoline vapors that escape from all parts of the vehicles other than that from the exhaust pipe. Permeation VOC emissions are the portion of evaporative VOC emissions that permeate through the plastic and elastomer materials in the vehicles fuel system and fuel containers that are in contact with the fuel. Gasoline related emissions are also grouped into two general sources of gasoline users which are the on-road vehicles and the off-road engine sources that are generally the smaller engines such as lawnmowers, chainsaws, power generators, etc. Even though these off-road sources consume only about 5% of the gasoline, they represent a significant share of the gasoline related VOC inventory (50+%).

The impacts of RFG on state emissions inventories can be estimated using a number of emission prediction models developed by EPA and CARB (California Air Resource Board). The vehicle fleet emissions can be estimated with EPA's MOBILE6.2 emissions model, and all states except California that have implemented RFG programs use the MOBILE model to estimate the benefits of RFG.<sup>1</sup> The EPA's MOBILE model which estimates on-road vehicle emissions, however, does not differentiate between RFG using MTBE and RFG using 10% ethanol. One reason for showing no difference is because data on the permeation characteristics of ethanol have only recently become available, and neither the MOBILE model nor EPA's model for estimating emissions from off-road equipment and vehicles (NONROAD) have been updated for these ethanol permeation effects. Another reason is that EPA emission models do not reflect the non-linear increase in NO<sub>x</sub> emissions associated with the higher oxygen levels in the 10% ethanol blends. Lastly, the EPA emission models do not include a model for small portable gasoline containers used for storing fuel for the off-road engines.

This section briefly reviews five studies which have presented the results of ethanol's impact on permeation VOC emissions. The five studies are:

- The Coordinating Research Council (CRC) Study
- The AIR, Inc. Permeation Study for the API
- The AIR, Inc. Fuels Study for Southeast Michigan Council of Governments
- California Air Resources Board Draft Study of Ethanol Effects
- California Air Resources Board Test Program for Permeation from Portable Containers

#### 3.1 CRC Study

When California implemented its Phase 3 RFG requirements calling for the phase-out of MTBE and replacement with ethanol, one of the issues raised during the Board Hearing was whether ethanol increased permeation emissions of VOC components through plastic and rubber

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<sup>1</sup> California uses its own emissions models. EMFAC is used for on-road vehicles, and OFFROAD is used for off-road equipment and vehicles, and portable gasoline containers.

parts in the fuel system of vehicles. The Air Resources Board directed their staff to study this issue. The CARB and the Coordinating Research Council (CRC) initiated a 2-year, 10-vehicle testing program to evaluate this issue. On September 20, 2004, CRC issued a detailed report summarizing the results of the testing. [1]

The testing program revealed that ethanol increases permeation emissions from on-road passenger cars and light duty trucks an average of 1.4 grams per day (g/day) per vehicle as compared to an MTBE fuel, under the test conditions of a diurnal temperature of 65° F to 105° F. The testing also found that this increase in permeation VOC emissions is sensitive to ambient temperature. At lower ambient temperatures, the increase in emissions due to ethanol is lower, so this indicated a need to correct for any differences in the ambient and test temperatures when estimating the increase in emissions.

### 3.2 AIR Permeation Study for API

Recognizing that the CRC data and report would be released, and desiring to determine the inventory impacts of expanding ethanol use, the American Petroleum Institute (API) contracted with AIR, Inc. to determine, based on the CRC on-road data, and other data that is available, the impact of ethanol on permeation emissions for on-road vehicles, off-road equipment, and portable containers. The study was conducted for several different areas of the country, including California, Atlanta, Houston, and the New York/New Jersey/Connecticut area. [2]

The study used the available data, developed temperature correction factors, and estimated the permeation VOC increases in the above geographical areas. For example, in California, the study estimated that ethanol increases permeation emissions from on-road vehicles, off-road sources, and portable containers by 25 tons per day (tpd) in 2003. The study further estimated that ethanol would increase VOC permeation by 24 tons per day in the New York/New Jersey/Connecticut area. These VOC increases are on the order of 5-6% of on-highway State Implementation Plan (SIP) VOC for New York and New Jersey areas.

### 3.3 AIR Study for SEMCOG

AIR also studied various gasoline and diesel fuel options for the Southeast Michigan Council of Governments. [3] SEMCOG evaluated a number of fuel options, including RFG with ethanol, RFG without ethanol, 100% ethanol in conventional gasoline, and other options. The methods used to estimate permeation emissions were consistent with the API report, and the NOx effects of ethanol were estimated with the California Predictive Model. This study found that RFG without ethanol would have larger VOC benefits than RFG with ethanol, due to lower permeation VOC emissions. The study also found that RFG with ethanol would increase NOx over Michigan baseline fuel, and that 100% ethanol fuel in Michigan gasoline would increase both NOx and VOC. The state of Michigan is currently considering lower RVP as a cost-effective means to further reduce VOC emissions.

### 3.4 California ARB Draft Study on Ethanol

The California Air Resources Board recently released a draft study of the effects of ethanol in California. [4] Similar to the AIR study for SEMCOG, ARB estimated the permeation effects for on-road vehicles, off-road equipment, and portable containers. ARB also estimated NOx impacts for on-road vehicles. This draft study concluded that ethanol increases VOC by 45-75 tpd, and that NOx increases by 21 tpd in California with ethanol as compared to MTBE.

### 3.5 California Air Resources Board Test Programs on Portable Containers

There is no specific ARB report on permeation of portable plastic fuel containers with and without ethanol, however, ARB has performed a number of tests with its certification fuel, which contains MTBE, and fuel containing 6 % ethanol. The data, which was obtained by AIR, Inc, is shown in Table 12 of the API study referenced earlier. [2] Basically, a number of different portable containers were tested, and the average size was about 3.3 gallons. The average emission rate on MTBE fuel was 4.7 g/day, and on fuel containing ethanol was 6.6 g/day, for an increase in VOC emissions of about 39%.

## 4.0 Methods

This section discusses the methods used to estimate emission impacts of converting to ethanol use in Maryland's RFG program.

### 4.1 Fuel Cases

Three fuel cases are being evaluated in this study, as follows:

#1: Baseline RFG with 11% MTBE

#2: RFG with 10% ethanol

#3: RFG without oxygenate

Detailed fuel properties for both of these fuel cases are developed in Section 5. In this study, the gasoline sales in the state of Maryland are assumed to be fully switched from MTBE to either ethanol or a non-oxygenate gasoline in calendar year 2007.

### 4.2 Pollutants and Evaluation Years

This study evaluates VOC, CO, and NO<sub>x</sub>, and PM emissions from on-road gasoline vehicles, off-road gasoline equipment, and portable gasoline containers. The evaluation year is 2007.

### 4.3 Models Used

This analysis uses the EPA MOBILE6.2 model for MTBE emissions for on-road sources, and the California ARB Predictive Model to adjust the exhaust emissions from gasoline vehicles for either 10% ethanol effects, or for no-oxygenate effects. Non-ethanol permeation evaporative emissions from on-road sources are estimated with MOBILE, as are the other evaporative emissions (hot soak, running loss, and diurnal).

For off-road equipment and off-road vehicles, this analysis uses the EPA NONROAD2004 model for all three fuels. Unlike the MOBILE model, the NONROAD2004 model can be used for all cases, because the exhaust emissions of off-road equipment and vehicles are generally not equipped with catalytic converters, oxygen sensors and other equipment that is sensitive to differences in oxygenates. These exhaust emissions of these sources generally only respond to changes in oxygen concentration, not the type of oxygen.

One change was made to the default NONROAD2004 model emissions response. The NONROAD model shows very little effect of oxygen content on VOC and PM emissions from two-stroke off-road engines, and was based on emission tests of only one engine. This analysis located tests on five other engines, and developed an updated VOC and PM response curve. This is further discussed in Section 4.3.1 below.

Since neither the MOBILE nor NONROAD models include the effects of ethanol permeation, these effects had to be developed outside the models. These emission impacts were

developed in a manner consistent with AIR’s analysis for both API and SEMCOG, discussed earlier. The ethanol permeation impacts are discussed in more detail in Section 6.

#### 4.3.1 Oxygen Effect on VOC and PM Emissions from Off-road 2-stroke Engines

As on-road vehicle emissions have been reduced, the proportion of VOC and PM emissions from off-road equipment has increased, thus, the effects of different fuels on these engines are more significant.<sup>2</sup> EPA developed the impacts of oxygen on off-road engines on the basis of one Yamaha two-stroke Moped engine. [5,6] These test results showed that increasing oxygen by 1% (by weight) reduced VOC by 0.6%, increased NOx by 18.6% (NOx is very low on these engines compared to VOC, and so this percent increase on a mass basis is almost insignificant), and reduced CO by 0.4%.

An examination of the literature turned up two other sources with tests of two-stroke engines that were tested on both oxygen and non-oxygenated gasolines. One study evaluated effects of ethanol fuel on emissions from snowmobile engines. [7] A second study by The College of Engineering Center for Environmental Research and Technology (CE-CERT) evaluated two 4.5 hp Sachs engines. [8] In all, five 2-stroke engines have been tested in various programs. This study developed oxygen impacts on HC, CO, NOx, and PM emissions from the 5 engines, as described in Attachment 1. The emission effects are shown in Table 1, as compared to the NONROAD model.

Source	HC	CO	NOx	PM
NONROAD	-0.6%	-6.5%	+18.6%	-
5-engine database	-2.4%	-3.0%	+9.5%	-2.6%

Table 1 indicates that the 5-engine database compiled for this study shows greater HC, and PM reductions, and less NOx increase than the 1 engine utilized in the NONROAD2004 model. The CO reduction is a little lower with the 5-engine database. The NONROAD2004 model was therefore updated for these oxygen effects, prior to running the model for any of the three fuel scenarios.

#### 4.4 Vehicle Miles Traveled for On-road Vehicles

Vehicle miles traveled for 2007 was obtained directly from the state of Maryland, and is shown in Table 2.

<sup>2</sup> Off-road engine emissions standards have been implemented by the EPA and ARB, but the overall reductions are not yet as great as for on-road vehicles.

Region	LDGV	LDGT12	LDGT34	HDGV
Baltimore Area	12415.1	8098.1	2792.2	466.8
Calvert County	363.4	237.0	81.7	15.3
Cecil County	604.7	394.4	136.0	37.6
Charles County	588.6	383.9	132.4	23.4
Frederick County	1353.6	882.9	304.4	72.0
Kent County	131.0	85.5	29.5	6.1
Montgomery County	3772.0	2460.4	848.3	134.3
Prince George's County	4318.6	2816.9	971.3	139.2
Queen Anne's County	462.2	301.5	104.0	19.9
Rural Areas	2880.8	1879.1	647.9	128.0
Washington County	948.8	618.9	213.4	54.3

#### 4.5 On-road Vehicle, Off-road equipment, and Container Populations

On-road vehicle, off-road equipment, and container populations for Maryland for calendar year 2007 are needed to estimate permeation impacts from each of these sources.

On-road vehicle populations for estimating permeation impacts were provided by the state. Off-road equipment and vehicle populations were determined directly from EPA's NONROAD2004 model. The NONROAD2004 model does not include portable container populations, but ARB's OFFROAD model includes both offroad equipment and portable container populations, and the percent of portable containers to gasoline equipment for the state is 47.3%. For this analysis, portable container populations in Maryland were determined by estimating the off-road gasoline equipment populations from the NONROAD model, and applying the ratio of portable containers to off-road gasoline equipment in OFFROAD to the NONROAD populations.

All of the populations for 2007 are shown in Table 3 below.

Source	Estimated 2007 Population
On-road gasoline vehicles (LDGVs, LDGTs, HDGVs)	4,231,214
Off-road gasoline equipment*	2,606,853
Portable gasoline containers (plastic only)	1,234,026

\*2 stroke and 4-stroke engines

#### 4.6 Other Inputs

AIR used the temperatures and speeds provided by Maryland. These are outlined in Table 4 below.

<b>Table 4. Minimum and Maximum Temperatures and Speeds</b>			
Region	Min Temp (F)	Max Temp (F)	Speed (mph)
Baltimore Area	67.6	94	40.65
Calvert County	68.5	95	39.49
Cecil County	67.6	94	42.52
Charles County	68.5	95	35.31
Frederick County	68.5	95	41.45
Kent County	67.6	94	37.28
Montgomery County	68.6	95	33.81
Prince George's County	68.5	95	36.83
Queen Anne's County	67.6	94	40.83
Rural Areas	67.6	94	36.66
Washington County	67.6	94	40.21

#### 4.7 Method of Combining Model Results

As noted above, the fuel options affect 3 major sources: on-road vehicles, off-road equipment and vehicles, and portable containers. This study examines the effects from all three sources. The general equation used to estimate these effects is the following:

$$\text{Total effect} = \text{On-road effect} + \text{off-road effect} + \text{portable container effect}$$

Where:

Onroad effect = Exhaust effect + Evaporative effect + permeation effect

Off-road effect = Same as on-road, but for off-road sources

Portable container effect = Permeation effect

And where:

Exhaust effect from onroad vehicles = MOBILE6.2 exhaust baseline \* % Change from Predictive Model

Evaporative effect from onroad vehicles = change in evaporative emissions as estimated by MOBILE6.2 directly

Permeation effect from onroad vehicles = method used by AIR in API permeation study

Exhaust effect from off-road vehicles = estimated by EPA NONROAD model

Evaporative effect from off-road vehicles = estimated by EPA NONROAD model

Permeation effect from off-road vehicles = method used by AIR in API permeation study

Permeation effect from portable containers = method used by AIR in API permeation study

## 5.0 Maryland Fuel Characteristics - 2007

Detailed fuel property estimates for the three fuels are shown in Table 5. The information for the baseline MTBE was based on survey data published by the EPA. [9]

Ethanol RFG properties were derived from the MTBE fuel property data, with the exception of the T50 level (temperature at which 50% of fuel is distilled). Examination of data from Delaware and Connecticut has shown that the T50 value with ethanol would increase about 5° F from the level with MTBE. Most of the other properties are not expected to change from the levels found in current gasoline containing MTBE in Maryland (properties that are expected to change are shown in **bold** type).

Both ethanol and MTBE have higher octane than gasoline that they are typically blended with, so when these oxygenates are removed, other gasoline properties (aromatics, benzene, and olefins) must be adjusted to reflect the increase non-oxygenated octane and loss of a clean diluent, while attempting to still meet the RFG emission reductions. To replace octane lost by removing oxygen, the aromatics, benzene, and olefins were increased, and the RVP was slightly reduced, so that the RFG requirements for VOC, NO<sub>x</sub>, and toxics were still met using EPA's Complex Model. The controlling pollutant is VOC; with this gasoline there is some NO<sub>x</sub> and toxics over-performance of the RFG specifications. While many different fuel properties for non-oxygenated gasoline are possible, all would involve increasing higher-octane components to some degree to replace lost octane, while simultaneously meeting the minimum RFG performance requirements.

<b>Table 5. Fuel Properties for Baseline and Ethanol Gasoline in Maryland</b>			
Property	MTBE RFG	Ethanol RFG	Non-oxygenate RFG
Oxygen (wt %)	<b>2.07</b>	<b>3.4</b>	<b>0.0</b>
Nominal Volume %	<b>11</b>	<b>10</b>	<b>0</b>
Benzene (vol %)	0.59	0.59	<b>0.66</b>
RVP (psi)	6.81	6.81	<b>6.71</b>
Aromatics (vol %)	19.1	19.1	<b>25.5</b>
Sulfur (ppm)	30	30	30
Olefins (vol %)	11.43	11.43	<b>12.8</b>
T50 (°F)	<b>201</b>	<b>206</b>	<b>210</b>
T90 (°F)	331	331	331
MTBE (vol %)	<b>10.3</b>	<b>0.0</b>	<b>0.0</b>
Ethanol (vol %)	<b>0.0</b>	<b>10.2</b>	<b>0.0</b>
TAME (vol %)	<b>1.1</b>	<b>0.0</b>	<b>0.0</b>

The EPA Complex Model used to develop some of the properties in Table 5 is based on pre-Tier 1 vehicles (pre-1994 model year), and may not be the best indicator of the percent changes in emissions of the fleet. The ARB Predictive Model, used by refiners in California, is more current in terms of having more vehicles of a more recent vintage, and updated statistical techniques. It is designed to represent the California fleet in calendar year 2005. A review of the

documentation of both the Complex and Predictive Models compels the author to conclude that the Predictive Model is a better indicator of the percent changes in exhaust emissions of the Maryland fleet than the EPA Complex Model. The above fuel property data in Table 5 was therefore inputted into the ARB Predictive Model. As indicated in the SEMCOG report, the Predictive Model estimates the change in emissions of any gasoline versus a reference gasoline, so procedures developed in the SEMCOG analysis were used to compare the two fuels in Table 5 to each other. The changes in exhaust VOC and NOx emissions are shown in Table 6.

<b>Table 6. Predictive Model Results</b>		
<b>(% change from MTBE to either Ethanol or non-Oxygenate RFG)</b>		
Fuel Change	Pollutant	% Change
MTBE to Ethanol	Exhaust VOC	+2.8%
	Exhaust NOx	+5.6%
MTBE to Non-Oxygenate	Exhaust VOC	+6.1%
	Exhaust NOx	0.0%

As noted in Table 6, the switch from MTBE to ethanol is expected to increase VOC by 2.8% and NOx by 5.6% in on-road gasoline vehicles. The increase in exhaust VOC is primarily due to the change in T50 levels, and the increase in NOx is due to ethanol. Since the fuel RVPs of the MTBE and ethanol RFG are expected to remain the same, there is no change in non-ethanol related permeation emissions and the other evaporative emissions (hot soak, diurnal, and running loss). There is an increase in ethanol-related permeation emissions, however, which is discussed in Section 6.

For a non-oxygenated gasoline, VOC is expected to increase by 6.1% and NOx is not expected to change. The increase in exhaust VOC is due to the addition of aromatics, benzene, and olefins which raise octane.

This study did not examine the changes in overall toxics, because the study includes non-road engines as well as on-road vehicles, and it is currently not possible to evaluate changes in fuel impacts on toxics for nonroad engines. Nonetheless, the ARB Predictive Model and EPA's RFG Complex Model for on-road vehicles provide an indicator of the difference in air toxics for onroad vehicles. The change in air toxics for the different fuels used in this study is shown in Table 7.

<b>Table 7. Percent Change in Total Onroad Toxics from MTBE Fuel to Either Ethanol RFG or non-Oxy RFG</b>		
	EPA RFG Complex Model	Calif Predictive Model
Fuel Change	Mass Basis	Risk Weighted Basis
MTBE to Ethanol RFG	+ 6 %	No change
MTBE to non-Oxy RFG	+ 14 %	+24%

Table 7 indicates that with ethanol, there is no change in total risk weighted air toxics. With the non-oxy RFG, there is a 24% increase in total on-road risk weighted air toxics and a 14% increase the mass of air toxics. Off-road toxics would also increase for this fuel, although it is not known by how much.

## 6.0 Permeation VOC Emissions

A recent extensive testing program conducted by the Coordinating Research Council shows that ethanol blends increase permeation VOC emissions from on-road vehicles by about 65% as compared to a MTBE blended fuel. Also, data from the California Air Resources Board shows that permeation VOC emissions also increase for off-road equipment, and portable containers used to store gasoline for off-road equipment and off-road vehicles. Based on the studies to date, the increase in permeation VOC's is a phenomena that is unique to ethanol blends and not other oxygenates such as ethers or MTBE. In fact, of the three fuels tested in the CRC study, MTBE blends had the lowest permeation emissions and were about 15% lower than the straight hydrocarbon blend, but this difference between MTBE blends and straight hydrocarbon is not conclusive since it fell within the statistical accuracy of the study data. Based on these results, using ethanol in the gasoline apparently increases the gasoline's solvency action on the non-metallic materials in contact with the fuel, which then contributes to higher permeation of the gasoline components through these materials as VOC emissions into the atmosphere.

The permeation effects of ethanol in this report are based on the results from the CRC study, and utilize the estimation methods developed in the study by AIR for the American Petroleum Institute (API). [2] Generally, the ethanol permeation impacts are a function of the population of the various sources (on-road vehicles, off-road equipment and vehicles, and portable containers), the ethanol permeation increase for each type of source, and the temperature correction factors for this permeation increase. The AIR study developed all these inputs for California, Atlanta, Houston, and the New York/New Jersey/Connecticut areas, but the same techniques have been applied in Maryland.

Permeation increases due to ethanol for various sources are shown as grams per day per unit of source (g/day/unit) in Table 8. These emission increases are for a 65-105° F test procedure with an average temperature of 85° F, and are corrected to the average temperature of the counties in shown in Table 4.

<b>Table 8. Permeation VOC Increases for Various Sources due to Ethanol</b>		
Source	Model Year Group	VOC Permeation Increase (g/day/unit)
On-road gasoline vehicles	Pre-1991	2.03
	1991-1995	0.86
	Enhanced evap (phase-in schedule varies by vehicle class)	0.80
	Tier II evap (phase-in schedule varies by vehicle class)	0.43
Off-road gasoline equipment	All	0.40
Recreational vehicles and recreational marine	Pre-2008	0.40
	2008+	0.123
Plastic portable fuel containers	All	1.86

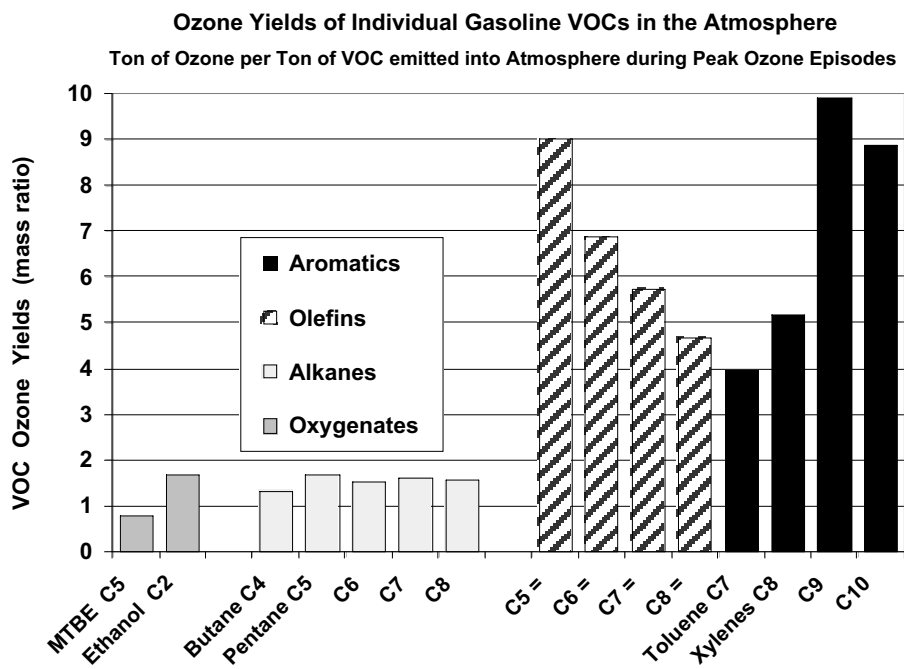
The values in Table 8 were developed on CRC tests that used E6 (6 volume % ethanol blend), instead of E10 (10 volume % ethanol blend), which will be used in Maryland. Assuming that permeation is a function of the ethanol content in the fuel, it is possible that this assumption could understate the ethanol permeation impact. While further testing of E10 is planned by the Coordinating Research Council, this analysis also estimated the emission impact as if the permeation impact is proportional to ethanol concentration in the gasoline. For the sensitivity case, permeation emissions were assumed to be 66% higher (10%/6%) because of the use of E10, instead of E6 in Maryland.

## 7.0 Atmospheric Reactivity of VOCs

Most state ozone control programs and inventory analysis will focus on controlling the total mass of ozone precursors emitted into the atmosphere such as NO<sub>x</sub> and VOCs under an implied assumption that all mobile source VOCs are equally potent in generating ozone on ozone episode days. However, vehicle VOC emissions are actually a large mixture of many different VOC components which produce different yields of ozone in the atmosphere depending on each VOC's individual chemical configuration or make-up which then effects it rate of reactivity in producing ozone. The VOCs found in gasoline are generally classified into four chemical groups which also determine their atmospheric reactivity. These four groupings are alkanes (paraffins), olefins, aromatics and oxygenates which then can be further differentiated by the number of carbon (C) atoms found in each individual VOC structure. Each of these VOCs that make up the VOC's in gasoline will have different levels of ozone producing reactivity associated with them as shown in Figure 1. These ozone yields reflect the ozone produced by each type of VOC under maximum incremental reaction (MIR) ozone producing conditions found in the atmosphere. These reactivity yields have been developed by Dr. Carter for use by the CARB (California Air Resource Board) in their ozone control programs. [10]

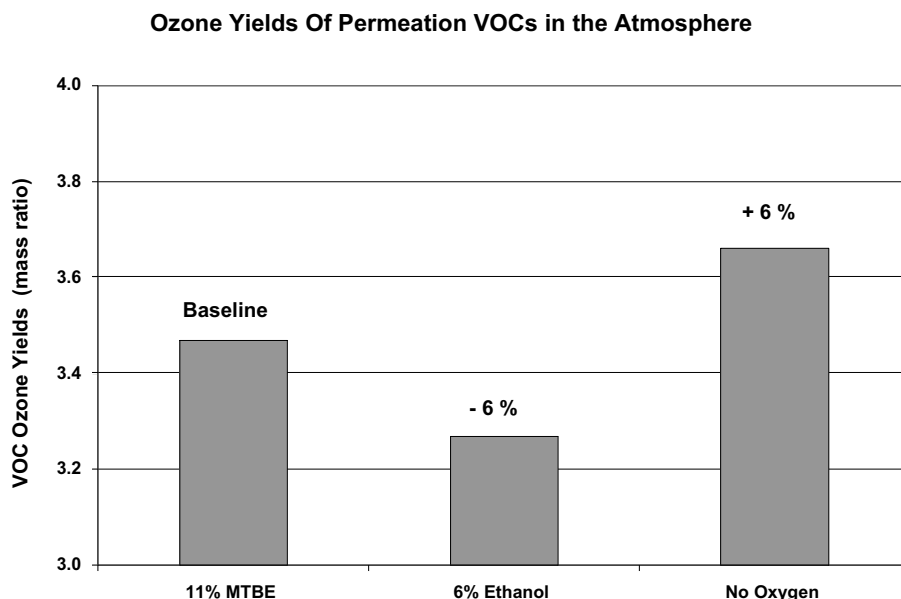
What is apparent from this data is that olefins and aromatics are very reactive in generating higher amounts of ozone in the atmosphere while alkanes (paraffins) and oxygenates are much slower or less reactive in generating ozone. Of all compounds blended in gasoline, MTBE is the least reactive (lowest ozone forming) which then suggests that any gasoline component used to replace MTBE will increase the overall reactivity of the VOC mixtures associated with gasoline's evaporative emissions.

Figure 1



This effect on VOC ozone yield can be observed in the recent CRC permeation study discussed earlier. [1] Figure 2 shows the calculated changes in ozone yield for the permeation VOC mixture for each of the three fuels in the study. Although ethanol has a higher reactivity than MTBE, the average reactivity of the ethanol VOC mixture is lowest because ethanol represents such a large percentage of the increased VOCs with the ethanol blend.

**Figure 2**



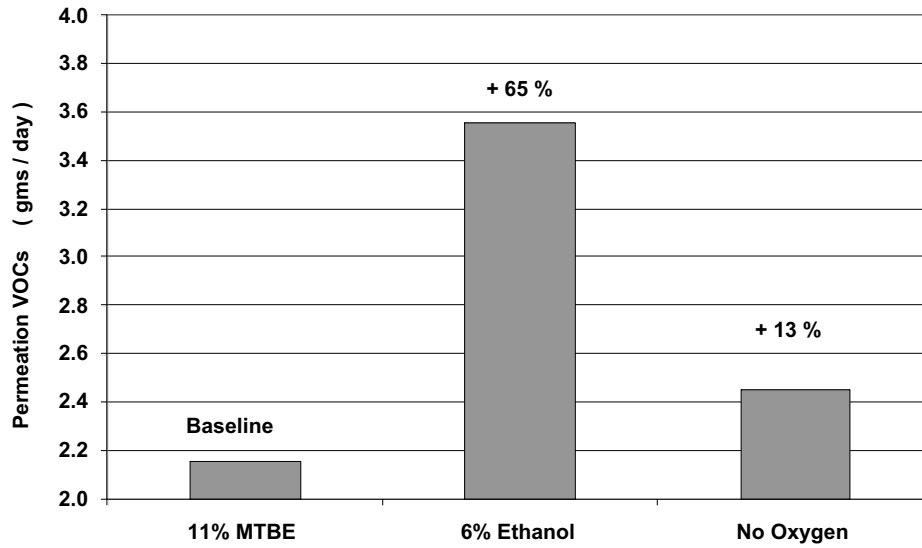
The daily permeation VOC masses per vehicle associated with each of the three fuels are shown in Figure 3. When the effects of the reactivity are applied against the VOC masses associated with the daily VOC permeations, the ozone production per vehicle for each of the three fuels can be calculated and is shown in Figure 4.

Therefore, when taking the reactivity of the VOC mixtures into consideration, the results from this CRC permeation study would suggest that the permeation VOCs from the ethanol blend would increase the ozone contribution by 55% compared to the MTBE blend, and the non-oxygenated blend would increase the ozone contribution by about 20%.

In this study, the change in reactivity of the VOC emission mixtures are not taken into consideration, but are shown here to illustrate that MTBE as a VOC is relatively inert in the atmosphere when it comes to generating ozone. Therefore, switching from MTBE to the other more reactive gasoline components might result in higher ozone production than would be estimated by just using percent changes in the VOC mass emission related to the use of the various fuels.

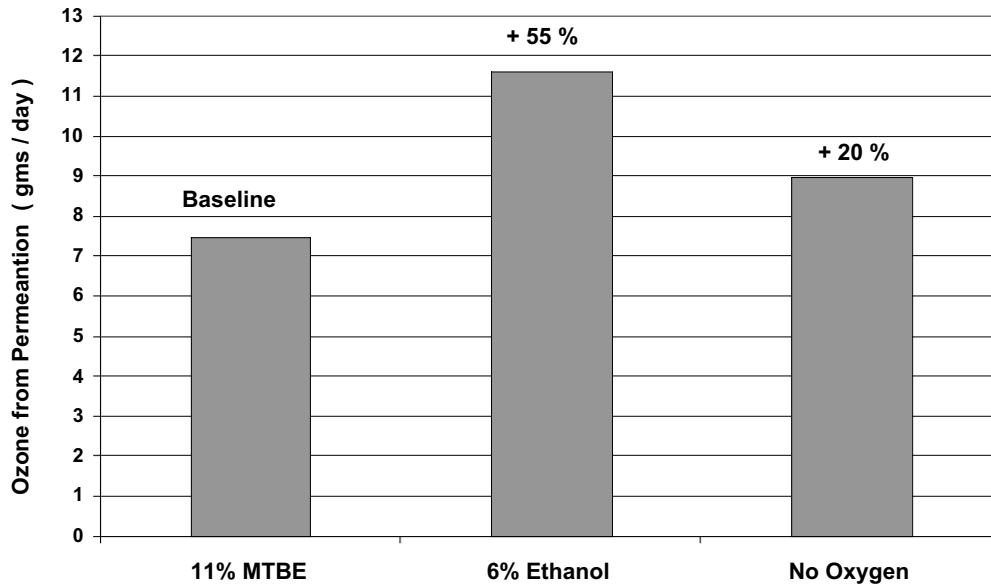
**Figure 3**

**Average Permeation VOCs per Day from Vehicles**



**Figure 4**

**Calculated Ozone Production From Permeation VOCs per Vehicle**



## 8.0 Results

### 8.1 Baseline Inventories

Baseline on-road and off-road VOC, CO, and NO<sub>x</sub> emission inventories for Maryland are shown in Table 9. This inventory summary does not include the portable container VOC inventory in the baseline, because this analysis is only estimating the increase in VOC emissions by adding the increase in permeation emissions for containers and vehicle fuel systems due to ethanol being added to the fuel.

Source	Exhaust VOC	Evaporative VOC	CO	NO <sub>x</sub>	PM <sub>10</sub>
On-road gasoline vehicles	46.4	55.3	1230.4	117.9	0.9
Off-road gasoline equipment and off-road gasoline vehicles	113.3	18.5	1766.8	16.2	6.4
Total mobile, gasoline	159.7	73.8	2997.2	134.1	7.3

The baseline inventory is 160 tons per day (tpd) of VOC (exhaust + evaporative), 2997 tpd of CO, 134 tpd of NO<sub>x</sub>, and 7.3 tpd of PM. These inventories may be somewhat different than the SIP inventories estimated by the state, because the state follows a much more detailed EPA approved procedure for estimating local inventories. However, the estimates developed in this study are sufficiently accurate since the focus of this analysis is on the “relative difference” in inventories due to a switch from MTBE to ethanol in the gasoline.

#### 8.1.1 Effect of Changes in the NONROAD Model on Emissions

Table 10 shows the changes in VOC, CO, NO<sub>x</sub>, and PM emissions from the default NONROAD model to the model used in this study, which was revised for the effects of fuel oxygen content on the emissions of 2-stroke engines.

Fuel	Pollutant	NONROAD Default	Updated NONROAD	Ratio (Updated/Default)
MTBE RFG	Exhaust THC	82.0	78.7	0.96
	CO	233.6	236.3	1.01
	NOx	3.8	3.3	0.86
	PM <sub>10</sub>	6.3	6.0	0.95
Ethanol RFG	Exhaust THC	81.3	76.0	0.93
	CO	210.2	214.8	1.02
	NOx	4.5	3.6	0.81
	PM <sub>10</sub>	6.3	5.8	0.91

The results in Table 10 show reductions in 2-stroke HC, NOx, and PM, and a slight increase in CO. The 4-stroke results were checked and they showed no change, and the 2-stroke results were also checked when the oxygen level in weight percent was set to 0.0, and these also showed no change, as anticipated. The updated model is used in the remainder of this analysis.

## 8.2 Emission Changes Due to Ethanol

### 8.2.1 On-Road Vehicles

On-road VOC, CO, and NOx gasoline vehicle inventories in 2007 with MTBE, ethanol, and non-oxy RFG are shown in Table 11.

Pollutant	Baseline – MTBE	Ethanol	No-Oxygenate	Change to Ethanol	Change to non-Oxygenate
Exhaust VOC	46.4	47.7	49.3	1.3	2.8
Evap VOC	55.3	55.3	55.0	0.0	-0.3
CO	1230.4	1230.4	1292.8	0.0	62.4
NOx	117.9	124.5	117.9	6.6	0.0
PM <sub>10</sub>	0.9	0.9	0.9	0.0	0.0

The exhaust VOC and NOx inventory increases are estimated by applying the percent increases in Table 4 by the MTBE inventories above. The CO inventory does not change, because the MOBILE model does not differentiate between RFG with MTBE and RFG with ethanol. The non-permeation related evaporative emissions change slightly because of the change in RVP (see RVP in Table 5).

### 8.2.2 Off-Road Vehicles

Off-road vehicle and equipment inventories in 2007 in Maryland on MTBE, ethanol, and non-oxy RFG fuels are shown in Table 12. Converting to ethanol RFG reduces off-road exhaust VOC because the emissions are a function of weight percent of oxygen instead of volume percent of oxygenate, and the weight percent of oxygen is higher for ethanol than for MTBE. The change to a no-oxy RFG will increase exhaust VOC by almost 8 tpd. For evaporative VOC, there is no change to an ethanol RFG, but there is a slight reduction in evaporative VOC (0.4 tpd) for no-oxy RFG because the fuel is estimated to have a 0.1 lower RVP. CO emissions display the same directional trends as VOC. NOx emissions increase for the ethanol fuel, but are reduced for the non-oxy RFG. Finally, ethanol will reduce PM by minus 0.2 tpd, but the non-oxy fuel will increase PM from two-stroke engines by 0.3 tpd.

Pollutant	MTBE	Ethanol	Non-Oxy RFG	Change to Ethanol	Change to non-Oxy
Exh VOC	113.3	108.2	121.1	-5.0	7.8
Evap VOC	18.5	18.5	18.1	0.0	-0.4
CO	1766.8	1597.8	2029.8	-169.0	263.0
NOx	16.2	18.1	13.2	1.9	-3.0
PM	6.4	6.2	6.7	-0.2	0.3

### 8.2.3 Permeation VOC Impacts

The permeation VOC impacts from using ethanol are shown in Table 13. The first estimate assumes that the permeation impacts in Maryland with 10% ethanol are the same as with 6% ethanol. The other assumption is that the permeation impact is proportional to ethanol concentration. Overall, VOC emissions in Maryland will increase by 6.6 -11.0 tpd due to the permeation effects of ethanol for the ethanol RFG. There is no change in permeation emissions for the non-oxy RFG.

Source	Based on 6% testing	Proportional to concentration
On-road gasoline vehicles	3.3	5.5
Off-road gasoline vehicles and off-road gasoline equipment	1.0	1.7
Portable gasoline containers	2.3	3.8
Total	6.6	11.0

## 8.2.4 Summary of Impacts

The summary of emission impacts for a change to either ethanol RFG or no-oxy RFG is shown in Table 14. In this table, we have assumed that the permeation effects are proportional to ethanol concentration (see Table 13).

Pollutant	Baseline Inventory – Gasoline (tons per day)	Net Ethanol Impact (tons per day)	Net Non-Oxy RFG Impact	% Change, Ethanol RFG	% Change, non-Oxy RFG
VOC	235.5	2.9 to 7.3	10.0	1.2% to 3.1%	4.3%
NO <sub>x</sub>	134.1	8.5	-3.0	6.3%	-2.2%
CO	2997.2	-169.0	325.5	-5.6%	10.9
PM	7.33	-0.22	0.34	-3.0%	4.6%

Table 14 shows that if Maryland bans MTBE and is replaced by ethanol RFG, VOC would increase by 1-3%, depending on the extent of the permeation effect, NO<sub>x</sub> would increase by 6%, CO would be 6% lower, and PM would be reduced by 3%. If the MTBE RFG is replaced by a non-oxygenated gasoline, VOC would increase by 4%, NO<sub>x</sub> would be reduced by 2%, CO would increase by almost 9%, and PM would increase by 5%. If the MTBE gasoline is replaced by a 50/50 mix of the two fuels, VOC would increase by 3-4%, NO<sub>x</sub> would increase by 2-3%, CO would increase by 3%, and PM would increase by 2%. This analysis assumes no “commingling” of the two fuels (commingling is discussed further in the next section).

The CO increases that would result with a non-oxygenated gasoline are not insignificant. CO is a weak ozone precursor, but the size of the changes is significant. EPA’s analysis of the tradeoff between CO and VO in the Chicago area estimated that that 45 tons of CO was worth 1 ton of VOC on a reactivity and mass basis. [11] Thus, if this is an appropriate ratio also for Maryland, the VOC equivalents derived from the CO benefit of converting to ethanol from MTBE would be worth about 169/45 tpd, or 3.8 tpd of VOC. This may mitigate part of the 7.1 tpd VOC permeation increase. However, under the no-oxy RFG scenario, CO increases by 325 tpd, which may be equivalent to about 7.2 tpd VOC. This would add to the already 10.4 tpd of VOC that would be experienced with non-oxy RFG.

## 9.0 Discussion

This study shows that switching from RFG with MTBE to RFG with ethanol or non-oxy RFG, or some combination thereof would have a variety of emission impacts in the state. If the ethanol/non-oxy mix were 50/50, all four pollutants, VOC, CO, NO<sub>x</sub>, and PM, would increase. Since the state has been experiencing ozone exceedences with the new more stringent 8-hour ozone standard, these increases in emissions will likely need to be offset by emission reductions from other sources for the state to attain and then maintain the 8-hour ozone standards.

In addition to the uncertainties in which type a fuel will replace RFG with MTBE – an ethanol RFG or non-oxy RFG or some combination – there are uncertainties in the effects for each replacement fuel. Table 14 showed a range of benefits if either a ethanol RFG or non-oxy RFG were used. If both fuels were supplied by gasoline marketers, the range of impacts would lie somewhere in that range, with some qualifications as indicated in the sections below.

The following discussion expands on some of the uncertainties in this analysis for the ethanol and non-oxy RFG.

### 9.1 Ethanol RFG

#### 9.1.1 VOC

The range in VOC impacts of 1% to 3% increases comes from the uncertainty in the impact of 10% ethanol blends on permeation emission increases. The 1% figure assumes that the permeation increases are the same at 10 vol % ethanol as at 6 vol % ethanol which is the ethanol concentration used in the CRC permeation study. The 3% increase assumes the permeation increase is proportional to ethanol concentration in the gasoline. The Coordinating Research Council is conducting further testing of 10% vol ethanol blends, and the results of this study should be available later this year.

This analysis also assumes that “all” vehicles traveling in Maryland are filled with RFG blends using either all ethanol, or all non-oxy RFG, which essentially would be assuming that only one of the two fuel formulations would be sold in Maryland. However, with the oxygen standard being removed from RFG, it is entirely possible that both fuels might be sold in the Maryland marketplace which then introduces the possibility for increased evaporative VOC emissions via a situation known as commingling. When both types of fuels are offered in the marketplace, then some vehicles will sometimes fill up with ethanol containing gasoline, and at other times with non-ethanol containing fuel in their tanks. These vehicles that switch back and forth will suffer increased VOC emissions due to increased RVP from the commingling of the two fuels in the tank. Commingling of ethanol and non-ethanol fuels with the same RVP results in a fuel mixture that has a higher RVP, which thereby increases evaporative VOC emissions. Commingling has been assumed to be zero in this analysis. However, if both fuels are offered in the marketplace, it may increase evaporative VOCs by about 0.5 ton per day over the simple averaging of the two fuel cases considered here.

The permeation VOC emission increases from off-road equipment in this analysis are based on lawnmowers. Lawnmowers have relatively small fuel tanks compared to other off-road equipment and vehicles. It is likely that the permeation impacts for off-road equipment are actually higher than estimated in this analysis; in fact, California ARB estimates a higher permeation VOC impact for off-road equipment.

#### 9.1.2 NO<sub>x</sub>

The on-road NO<sub>x</sub> impacts of ethanol are based on the current ARB Predictive Model. The Coordinating Research Council has completed additional testing of the effects of ethanol on NO<sub>x</sub> emissions, and ARB plans to update its Predictive Model based on this testing later this year. The off-road NO<sub>x</sub> impacts are based on EPA's NONROAD model; no updates to this model for the NO<sub>x</sub> impacts are expected.

#### 9.1.3 CO

The fact that oxygenates reduce CO from the on-road and off-road fleet is well known and quantified in both the MOBILE6.2 and NONROAD models. The major debate concerns the relative reactivity of CO as an ozone precursor.

#### 9.1.4 PM

In this analysis, we did update the effects of oxygen on PM for 2-stroke off-road engines. It is likely that oxygen in the fuel also reduces PM from on-road vehicles and particularly "smoking" vehicles, although this effect has not been estimated or included in the MOBILE6.2 model. Also note that these PM estimates are only for primary PM which is emitted directly in the exhaust of these engines. These PM estimates do not include the amount or effect on secondary PM that are secondary aerosols which are formed by the atmospheric reaction of some of the exhaust gases. A significant source of carbonaceous PM in the atmosphere is the secondary aerosols formed by partially oxidizing the unburned gasoline aromatics found in the exhaust gases of gasoline engines. Therefore, reducing the amount of aromatics in the exhaust or the amount of exhaust and evaporative VOC from gasoline vehicles and equipment should also reduce the amount of carbonaceous secondary PM formed in the atmosphere.

### 9.2 Non-Oxy RFG

#### 9.2.1 VOC

For on-road vehicles, the non-permeation related evaporative emissions are simply tied to the RVP; if the RVP is a little lower than current, the evaporative emissions will be lower, and if the RVP is a little higher than current, then evaporative emissions will be a little higher. In this case there is no ethanol, so there is no increase in permeation emissions under this scenario. We have used the ARB Model to assess the impact on exhaust VOC. The model is the best we have for this application, although a new Predictive Model may be available soon that utilizes more test data from CRC. The major uncertainty in this respect is how much the aromatics, benzene, and olefins will increase to make up lost octane.

The evaporative emissions for nonroad vehicles behave similarly to RVP as onroad vehicles. The exhaust emissions are primarily a function of the oxygen content. One issue with respect to offroad equipment is that the current NONROAD model does not include running loss, hot soak, or diurnal emissions. If these emissions were included there would be larger swings in the RVP effect on evaporative emissions.

### 9.2.2 NO<sub>x</sub>

For both on-road and off-road vehicles, the reduction in NO<sub>x</sub> due to this scenario is a direct results of the reduction in ethanol. The amount of the decrease in NO<sub>x</sub> is probably more uncertain for on-road vehicles. The CRC will be shortly releasing test data from its E-67 program, which tested a variety of ethanol and non-ethanol fuels. Preliminary indications are that there is still an ethanol effect on NO<sub>x</sub> for new technology vehicles (I.e., LEVII and Tier II vehicles).

### 9.2.3 CO

The loss in CO benefits for both on-road and off-road vehicles if oxygen is removed from RFG is well known. There is much less impact of the other fuel parameters on CO.

### 9.2.4 PM

PM emissions in on-road gasoline and off-road gasoline engines come from combusting fuel lubricating oil, and metals, and sulfur. As far as the fuel is concerned the three most important properties of the fuel that affect PM are sulfur, aromatics, and oxygen content. Sulfur is being drastically reduced through the Tier 2/sulfur controls. But aromatics are expected to increase with this fuel, along with the loss of oxygen, which reduces PM. The increase in aromatics in gasoline may also have an effect on the carbonaceous secondary PM formed in the atmosphere from the engine exhaust gases that has been discussed in the previous PM section.

## 10.0 References

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4. “A Summary of the Staff’s Assessment Regarding the Effect of Ethanol in California Gasoline on Emissions”, Draft Report, February 2005, California Air Resources Board.
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10. “The SAPRAC-99 Chemical Mechanism and Updated VOC Reactivity Scales”, <http://helium.ucr.edu/~carter/reactdat.htm>.
11. “VOC Adjustment Rule: Response to Comments”, EPA420-R-01-017, June 2001, U.S. EPA.

**Attachment 1**  
Analysis of Oxygen Effects on Two-Stroke Engine Emissions

The NONROAD model oxygen effects for two-stroke engines are based on tests on one moped engine tested on both MTBE and ethanol blends at two different oxygen levels. The results are shown in Table 1-1 below. Note that EPA did not estimate a PM effect. The “average” effects were used in NONROAD.

Fuel Used	HC (%/% oxygen)	NOx (%/% oxygen)	CO (%/% oxygen)
2.7% oxygen	-0.4	18.4	-0.4
3.4% oxygen	-0.8	18.8	-12.5
Average effect	-0.6	18.6	-6.5

Additional 2-stroke engine tests were identified in this study, from a 1997 SAE paper which discussed tests on two snowmobiles, and from a study by CE-CERT, which examined ethanol effects on two 4.5 SACHS engines. The characteristics of these engines are shown in Table 1-2 (engines 2-5; engine 1 is the moped engine referenced by the EPA), and the emission test results of these engine tests, along with the data referenced by EPA, are summarized in Table 1-3.

Engine	Source	Use	HP	Brand	Age
1	SAE911222	Moped	6	Yamaha	?
2	SAE972108	Snowmobile	64	1997 Polaris	New
3	SAE972108	Snowmobile	56	1995 Arctco	2 years
4	CE CERT	Unknown	4.5	SACHS	New
5	CE CERT	Unknown	4.5	SACHS	Old

Engine	Oxygen	HC-Only Fuel (g/kW-hr)				Fuel Containing Oxygenates (g/kW-hr)			
		HC	CO	NOx	PM	HC	CO	NOx	PM
1	3.18	183	183	2.45	7.83	177	143	3.76	7.34
2	3.43	201	548	0.68	2.41	155	476	0.59	1.82
3	3.43	209	487	0.66	4.63	220	459	0.70	4.51
4	2.05	269	621	0.57	2.27	244	579	0.51	2.19
5	2.05	210	486	0.47	1.44	202	470	0.42	1.36
Avg	2.83	214	465	0.94	3.72	199	425	1.20	3.45

Table 1-4 shows the absolute difference in average emissions with test results in Table 1-3, and also the percent change in emissions per weight percent of oxygen.

<b>Table 1-5. Emission Reductions Due to Oxygen</b>				
Parameter	HC	CO	NO <sub>x</sub>	PM
Difference in emissions, g/kW-hr	15	40	-0.26	0.27
Percent difference per weight percent of oxygen	2.4%	3.0%	-9.5%	2.6%

Table 1-5 shows that while the percent increase for NO<sub>x</sub> appears large, its affect on a mass basis is very small. The reductions for the other pollutants, while smaller in percent terms, are much more significant on a mass basis because of their much higher baseline levels.

## **Attachment 2**

### **Background on Air Improvement Resource, Inc.**

Air Improvement Resource was founded in 1994, and conducts emissions, ambient air quality, and meteorological related research for a variety of industrial and governmental concerns. AIR has four employees, and is located near Detroit, Michigan. AIR is most widely known for its work on many projects with the two Federal and two California on-road and off-road emissions models. Recent projects include:

- Analyzing carbon monoxide emissions data on certification vehicles to determine impacts of cold temperatures (Coordinating Research Council)
- Estimating the emission changes associated with different fuels in the Southeast Michigan Area (SEMCOG, Alliance of Automobile Manufacturers, and American Petroleum Institute)
- Analysis of the emission inventory impacts of ethanol permeation (American Petroleum Institute)
- Analysis of the impact of MMT in gasoline in emissions in the U.S. and Canada (Alliance of Automobile Manufacturers and Canadian Vehicle Manufacturers Association)
- Revisions to the ARB OFFROAD Emissions Model (California Air Resources Board)
- Revisions to the EPA NONROAD Emissions Model (Environmental Protection Agency)
- Evaluation of options for meeting California's Phase 3 Exhaust and Evaporative Emission Standards for Small Gasoline Off-road Engines (Briggs and Stratton Corporation, and Engine Manufacturers Association)
- Ongoing evaluation of the EPA MOVES Model (Alliance Of Automobile Manufacturers)
- Evaluation of New ARB On-road EMFAC Model (Alliance of Automobile Manufacturers, and Engine Manufacturers Association)

The three technical employees of AIR are Tom Darlington, Dennis Kahlbaum, and Jon Heuss. Tom Darlington is an engineer with 25 years developing emission models, with experience at the EPA, Detroit Diesel Corporation, General Motors, and as a consultant. Dennis Kahlbaum is a meteorologist/ computer programmer with 25 years experience programming emission models, analyzing meteorological and emission data, and forecasting weather trends, with experience at Computer Sciences Corporation (for EPA), Consumers Energy Corporation, and AIR. Jon Heuss is a Principal Scientist with 40 years experience at General Motors who has played a major role in the review of the national and state ambient air quality standards. More information on the company can be found at "[airimprovement.com](http://airimprovement.com)."