Gina McCarthy, Commissioner
Connecticut Department of Environmental Protection

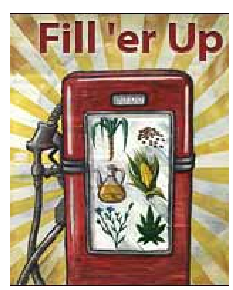
Dr. J. Robert Galvin, Commissioner
Department of Public Health

# Public Act No. 06-53, Section 6

# Analysis of the Use of Ethanol as a Fuel Additive

Report to the Joint Committee on
The Environment and the Joint Committee on Public Health of the
Connecticut General Assembly

## December 2006




**The DEP is an affirmative action/equal opportunity employer. In conformance with the ADA individuals with disabilities who need information in an alternative format, to allow them to benefit and/or participate in the agency's programs and services, should call TDD (860)-424-3000 and make their request to the receptionist. Requests for accommodations to attend meetings and/or educational programs, sponsored by the DEP, must be made at least two weeks prior to the program date.**

**These requests may be made directly to Marcia Z. Bonitto, ADA Coordinator, via e-mail: Marcia.Bonitto@po.state.ct.us**

**For additional information see the DEP Website at http://www.dep.state.ct.us/.**

**Cover Photos:** Patrice Kelly, The Grist, Renewable Fuels Association

# STATE OF CONNECTICUT
## DEPARTMENT OF ENVIRONMENTAL PROTECTION

December 29, 2006

Senator Christopher Murphy, Co-Chair
Representative Peggy Sayers, Co-Chair
Public Health Committee, Room 3000
Legislative Office Building
Hartford, Connecticut 06106

***Re: Analysis of the Use of Ethanol as a Fuel Additive: Report to the Joint Committee on the Environment and to the Joint Committee of Public Health of the Connecticut General Assembly Pursuant to Public Act 06-53***

Dear Senator Murphy and Representative Sayers:

In 2006, the Connecticut General Assembly enacted Public Act 06-53 (the Act). The Act directed the Departments of Environmental Protection (DEP) and Public Health (DPH) to conduct a study of the effects related to the use of ethanol as a fuel additive in Connecticut. As mandated, DEP and DPH developed the enclosed report. This report provides analyses, updates and recommendations, in accordance with the requirements outlined in the Act, but constrained by the limited resources available.

The enclosed report concludes that while the use of ethanol in gasoline does not cause the release of any unique air toxics, the air quality impacts are mixed. Ethanol has the positive effects of reducing emissions of some air pollutants and greenhouse gases, but its negative effects include increased emissions of ozone precursors due to evaporation from permeation. The key findings of this study include:

- The 10% ethanol fuel blends used in Connecticut displace 10% of the gasoline, helping to reduce the state's dependence on fossil fuels, as set out in the Connecticut Energy Plan.
- The Energy Policy Act of 2005 restricts states from adopting new "boutique fuels" programs; any state requirement that expands, limits or prohibits the use of ethanol in gasoline blends could constitute the creation of a new boutique fuel.
- Ethanol fuels aid in achieving the greenhouse gas reductions needed to meet the goals of the Climate Change Action Plan.
- Recent studies suggest that air pollution increases may result from the permeation of ethanol-blended fuels through vehicle fuel systems.
- Exhaust emissions and evaporation are expected to decrease over time as Connecticut's vehicle fleet is replaced with cars that meet the California Low Emission Vehicles Standards (Cal LEV II).

Quantification of specific changes in atmospheric levels of air pollution, both criteria pollutants and air toxics, cannot be derived from the available data and would require a resource commitment commensurate with the fiscal note on the bill. The most detailed studies evaluated for this report are based on fuel blends and climate conditions for California. There is substantial uncertainty in extrapolating the conclusions to Connecticut. The exposures that might jeopardize the health of Connecticut citizens can be derived from existing studies, but cannot be reliably quantified. However, because studies are currently underway that will improve the potential to make quantitative assessments for Connecticut, additional research is not warranted at this time.

To assure the varied perspectives and best information was provided to the Connecticut General Assembly, the DEP invited stakeholders to attend an informational presentation in September and to comment on the draft report in December. Communication and input on the draft report was also facilitated by posting the draft report on the DEP website.

We welcome the opportunity to work with you to build on our ongoing stakeholder process and provide real gains for Connecticut's environment and the citizens of this State. Thank you for your commitment to effective pollution control strategies to protect the health of Connecticut citizens. We look forward to continued legislative support to protect the environment in the state.

Yours truly,

Gina McCarthy
Commissioner, DEP

J Robert Galvin M.D., M.P.H.

Dr. J. Robert Galvin
Commissioner, DPH

GM/TRB/ppk
Enclosure

cc: Tom Tyler, DEP

# STATE OF CONNECTICUT
## DEPARTMENT OF ENVIRONMENTAL PROTECTION

December 29, 2006

Senator Bill Finch, Co-Chair
Representative Richard Roy, Co-Chair
Environment Committee, Room 3200
Legislative Office Building
Hartford, Connecticut 06106

***Re: Analysis of the Use of Ethanol as a Fuel Additive: Report to the Joint Committee on the Environment and to the Joint Committee of Public Health of the Connecticut General Assembly Pursuant to Public Act 06-53***

Dear Senator Finch and Representative Roy:

In 2006, the Connecticut General Assembly enacted Public Act 06-53 (the Act). The Act directed the Departments of Environmental Protection (DEP) and Public Health (DPH) to conduct a study of the effects related to the use of ethanol as a fuel additive in Connecticut. As mandated, DEP and DPH developed the enclosed report. This report provides analyses, updates and recommendations, in accordance with the requirements outlined in the Act, but constrained by the limited resources available.

The enclosed report concludes that while the use of ethanol in gasoline does not cause the release of any unique air toxics, the air quality impacts are mixed. Ethanol has the positive effects of reducing emissions of some air pollutants and greenhouse gases, but its negative effects include increased emissions of ozone precursors due to evaporation from permeation. The key findings of this study include:

- The 10% ethanol fuel blends used in Connecticut displace 10% of the gasoline, helping to reduce the state's dependence on fossil fuels, as set out in the Connecticut Energy Plan.
- The Energy Policy Act of 2005 restricts states from adopting new "boutique fuels" programs; any state requirement that expands, limits or prohibits the use of ethanol in gasoline blends could constitute the creation of a new boutique fuel.
- Ethanol fuels aid in achieving the greenhouse gas reductions needed to meet the goals of the Climate Change Action Plan.
- Recent studies suggest that air pollution increases may result from the permeation of ethanol-blended fuels through vehicle fuel systems.
- Exhaust emissions and evaporation are expected to decrease over time as Connecticut's vehicle fleet is replaced with cars that meet the California Low Emission Vehicles Standards (Cal LEV II).

Quantification of specific changes in atmospheric levels of air pollution, both criteria pollutants and air toxics, cannot be derived from the available data and would require a resource commitment commensurate with the fiscal note on the bill. The most detailed studies evaluated for this report are based on fuel blends and climate conditions for California. There is substantial uncertainty in extrapolating the conclusions to Connecticut. The exposures that might jeopardize the health of Connecticut citizens can be derived from existing studies, but cannot be reliably quantified. However, because studies are currently underway that will improve the potential to make quantitative assessments for Connecticut, additional research is not warranted at this time.

To assure the varied perspectives and best information was provided to the Connecticut General Assembly, the DEP invited stakeholders to attend an informational presentation in September and to comment on the draft report in December. Communication and input on the draft report was also facilitated by posting the draft report on the DEP website.

We welcome the opportunity to work with you to build on our ongoing stakeholder process and provide real gains for Connecticut's environment and the citizens of this State. Thank you for your commitment to effective pollution control strategies to protect the health of Connecticut citizens. We look forward to continued legislative support to protect the environment in the state.

Yours truly,

Gina McCarthy
Commissioner, DEP

J Robert Galvin M.D., M.P.H.

Dr. J. Robert Galvin
Commissioner, DPH

GM/TRB/ppk
Enclosure

cc: Tom Tyler, DEP

# Table of Contents

**Public Act 06-53 (Sec. 6)**
Analysis of the use of Ethanol as a Fuel Additive

**Report to the Joint Committee on the Environment of the Connecticut General Assembly**
**December 29, 2006**

Prepared by

**The Connecticut Department of Public Health and**
**The Connecticut Department of Environmental Protection**

## Executive Summary

In 2006 the Connecticut General Assembly enacted Public Act 06-53 (the Act),[1] which directed the Departments of Environmental Protection (DEP) and Public Health (DPH) to study the costs and benefits of using ethanol as a gasoline additive to meet federal Clean Air Act (CAA) requirements.[2,3] Accordingly, DEP and DPH have collaborated in the development of this analysis of ethanol as a fuel additive. The Act identified the following topics for examination:

- The public health implications of exposure to unsafe levels of ethanol and hazardous air pollutants (air toxics) unique to ethanol-blended gasoline,
- How using ethanol affects motor vehicle emissions and the state's implementation plan under the CAA, and
- Health risks associated with chronic exposure to ethanol or ethanol-blended gasoline.

The Act further delineated the following specific analyses, updates and recommendations to be included in the report:

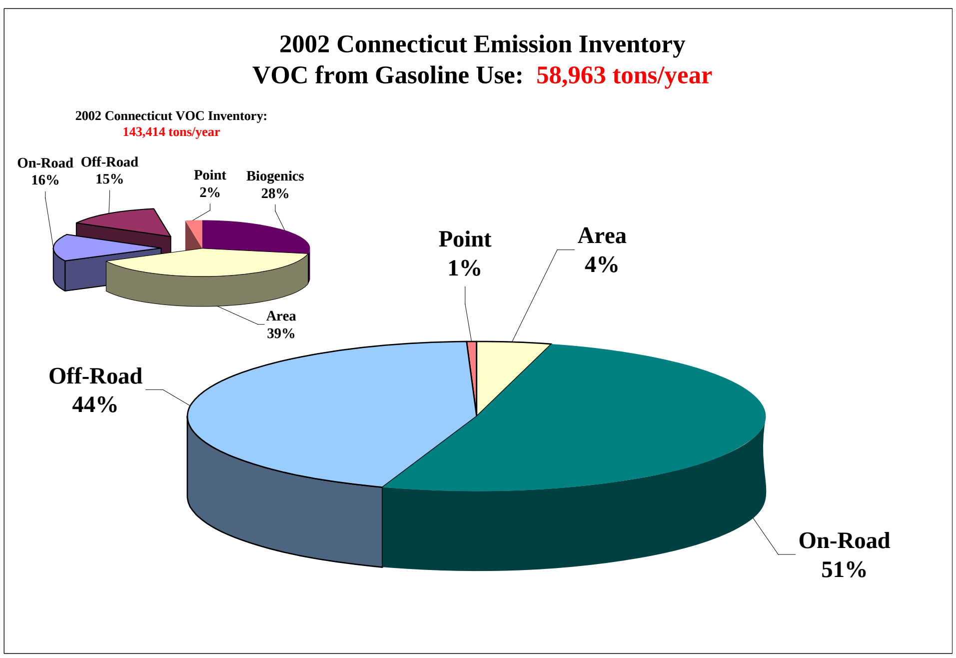
- An analysis of any reports or recommendations made by the Northeast States for Coordinated Air Use Management (NESCAUM) and the New England Interstate Water Pollution Control Commission (NEIWPCC),
- An analysis of whether Connecticut should continue to use ethanol as a gasoline additive and, if not, an analysis of the process for seeking a waiver from the United States Environmental Protection Agency (EPA) in order to discontinue the use of ethanol as a gasoline additive in this state,
- An analysis of the effect of ethanol on the state's air quality,

[1] For a full text of Public Act 06-53, see Appendix 1 on page 28.
[2] The study was limited to an analysis of existing literature on the subject. DEP provided a fiscal note estimated at $250,000 to undertake modeling and analysis to determine the environmental considerations of ethanol's effects on emissions, the state's air quality and the impacts on the state implementation plan (SIP). The General Assembly did not include funding as part of the adoption of the Act and, as a result, all analyses and evaluations have been developed within available appropriations of DEP and DPH. Staff members have been diverted from other priorities to complete this study. Therefore, this report provides analyses, updates and recommendations, in accordance with the requests outlined in the Act, but within the limited scope of available resources.
[3] Although biodiesel and other biofuels, present additional options as renewable fuel resources, this report is limited by the Act to ethanol; consideration of biofuels is beyond the scope of this study.

- An update on the status of any action taken by other states regarding the use of ethanol as a gasoline additive,
- Recommendations for new ethanol exposure standards for gasoline related occupations and for sensitive population subgroups, and
- Specific recommendations on alternative or supplemental air pollution reduction programs such as alternative motor vehicle fuel incentives, mass transit and employee commuter programs.

In 2005, gasoline consumption in Connecticut was estimated to be 1.65 billion gallons. Ethanol currently displaces 10% or 165 million gallons of petroleum based gasoline annually. The use of ethanol highlights two air quality issues normally associated with fuel combustion: 1) some pollutants, volatile organic compounds (VOCs) and nitrogen oxides ($NO_X$), react to produce ozone; and 2) some of the pollutants, VOCs and others, are air toxics. As is represented in Figure 1, Connecticut's VOC emissions from gasoline were estimated to be 58,963 tons per year in 2002. While the chart shows some contribution from point and area sources (gas pumps and terminals), this report is limited to emissions from on-road and off-road engines. Among the VOCs from gasoline are a variety of toxic chemicals, most notably benzene, ethylbenzene, xylene and toluene. These can evaporate into the air either directly, through vehicle venting systems and leaks, or by permeation through a vehicle's fuel system. The combustion of gasoline creates additional air pollutants which raise particular health concerns. Among them are 1,3-butadiene, a carcinogen, and formaldehyde and acetaldehyde, which are both carcinogenic and have the ability to cause acute irritation.

**Figure 1: Annual VOC Emissions from Gasoline in Connecticut, 2002**[4]




Until January 2004, the fuel oxygenate methyl tertiary butyl ether (MTBE) was added to gasoline to enhance octane and to meet minimum oxygen requirements. Oxygen helps gasoline

[4] Connecticut DEP, 2002 Periodic Ozone and Carbon Monoxide Emissions Inventory, Final, December 2005.

burn more completely and thus reduces tailpipe emissions resulting from incomplete combustion. Ethanol has replaced MTBE as a fuel oxygenate in Connecticut. Thus, the use of ethanol in gasoline has to be evaluated against the baseline conditions of either no oxygenate in the fuel or fuel with MTBE. This report summarizes the possible environmental and health risks associated with the change in gasoline formulation from MTBE to ethanol; such risks may result from the evaporative and combustion emissions of gasoline to the atmosphere and from gasoline leaks into groundwater. It also addresses the displacement of a significant amount of gasoline by ethanol in the 10% blend (E-10) currently used in Connecticut.

DEP and DPH conducted a literature search[5] and evaluated several studies showing correlations between emissions of air pollutants of concern, including the VOCs,[6] and the differences in fuel blends that have been formulated to stabilize volatility under different climate conditions. These studies are simulations and are thus only estimates of real world evaporative or combustion emissions. Added to this uncertainty is the fact that the studies were conducted in California using fuel blends[7] and weather conditions[8] that do not relate well to Connecticut. Thus, while these studies are the most detailed currently available, they do not allow precise emission estimates from ethanol fuels blended for use in New England. The following variables, which influenced the conclusions of the published analyses, limit the ability to draw conclusions regarding air quality impacts in Connecticut:

- The base fuels used are specific California blends which are distinct from seasonal blends used in Connecticut;
- The fleet mixes used in the published studies are not representative of Connecticut's current light-duty vehicle fleet; and
- Evaporative emissions were measured for a particular day and night temperature cycle that is not representative of Connecticut's daily and seasonal temperature variations.

Ethanol's displacement of petroleum-based gasoline has the beneficial effect of reducing the emissions of CO, benzene, which is an air toxic, and some hydrocarbons produced by combustion.[9,10] However, the improved combustion that yields those reductions may lead to increased production of $NO_X$ and permeation emissions may increase VOCs. Because data are not available for the E-10 fuels blended for use in Connecticut, reliable estimates for the effect of

---

[5] The literature search conducted for this report by NESCAUM, with summaries, appears in Appendix 2 on page 32; references used by DPH and DEP are compiled in Appendix 3 on page 44, and additional citations to ethanol health, environmental and energy policy documents appear in Appendix 4 on page 47.

[6] The VOC emissions include the following toxic pollutants of interest: benzene, acetaldehyde, formaldehyde, peroxyacetyl nitrate and 1,3-butadiene.

[7] CRC, Interim Report Summary: Fuel Permeation from Automotive Systems: E0, E6, E10 and E85, CRC Project No. E-65-3, August 2006, page 11. (Presented at CARB Fuels Workshop by Mike Ingham, 8/11/06, http://www.aqmd.gov/tao/ConferencesWorkshops/06_EthanolWS/Ethanol_Forum_Agenda.htm.) Hereinafter referred to as CRC Project No. E-65-3, August 2006.

[8] Ibid. at page 3.

[9] NEIWPCC and NESCAUM, Health, Environmental, and Economic Impacts of Adding Ethanol to Gasoline in the Northeast States, July 2001,Volume 2, Page 10. Link to NESCAUM/NEIWPCC Report Hereinafter referred to as NEIWPCC/NESCAUM (2001). A summary of the recommendations from this report appears in Appendix 5 on page 49.

[10] Koshland, Catherine P., Sawyer Robert F., Lucas, Donald, and Franklin, Pamela, Evaluation of Automotive MTBE Combustion Byproducts in California Reformulated Gasoline, *Report to California State Legislature under S.B. 521: Effects of MTBE* http://www.tsrtp.ucdavis.edu/mtberpt/vol3_1.pdf.

blending ethanol into fuel cannot be generated. Additionally, based on available data, it is not possible to reliably estimate the impact, if any, on ambient concentrations of aldehydes and other toxic pollutants that may accompany the replacement of MTBE blended RFG with E-10 in Connecticut. Without conducting further detailed studies, including lab testing, modeling and monitoring similar to the analyses conducted in California, DEP and DPH are not in the position to make recommendations regarding the use of ethanol-blended gasoline in Connecticut. Studies currently underway may begin to resolve these issues. Because such studies are quite costly, Connecticut should not consider a new research program until these studies have been published and evaluated.

Connecticut's implementation of the California Low Emission Vehicle Program (LEV II), beginning with the 2008 model year, will initiate the changeover in Connecticut's vehicle fleet to vehicles equipped with emission controls that reduce both exhaust emissions and evaporative emissions of VOCs and other air toxics, thus limiting any further effect on air quality.

Another consideration is the restriction on a state's ability to adopt a "boutique fuels" program, which was set out in the Energy Policy Act of 2005 (EPAct). Any state requirement that either changes the concentration or limits or prohibits the use of ethanol in RFG could constitute the creation of a new boutique fuel. Under EPAct there are hurdles that will be difficult to overcome; these must be considered in planning future strategies.

In spite of these uncertainties, the data generated from California studies suggest relatively minor changes to automotive emissions from the use of ethanol as an oxygenate in gasoline. This conclusion is based upon the fact that there are numerous background sources for fuel-related emissions so that the modest changes that may be possible from ethanol-blended gasoline can be expected to have an overall minor impact on air quality. Therefore, while data of direct relevance to Connecticut are not available, that which is available does not suggest the ethanol will significantly degrade air quality or lead to public health risk.

## Preliminary Findings

- No published reports to date have changed the conclusion reached in the NESCAUM 1998 report[11] that the addition of MTBE to gasoline displaces components that pose a greater cancer risk. Since ethanol is less of a cancer concern than MTBE, this is even more the case for ethanol-blended fuels.

- Connecticut's implementation of the California LEV II Program,[12] beginning with the 2008 model year, will initiate a changeover in Connecticut's vehicle fleet that significantly decreases air pollution.
    - Exhaust emissions are greatly reduced in low emission vehicles (LEVs).[13,14]

[11] NESCAUM, Relative Cancer Risk of Reformulated Gasoline and Conventional Gasoline Sold in the Northeast, Table ES-1 Method 3 Cancer Potency Ratios, 1998, p. ES-5. Hereinafter referred to as NESCAUM (1998)
[12] Regulations of Connecticut State Agencies (R.C.S.A.) Sec. 22a-174-36b.
[13] Recent studies indicate that emissions reductions may depend upon the type of fuel used. CRC, Effects of Ethanol and Volatility Parameters on Exhaust Emissions, CRC Project No. E-67, January 30, 2006. Hereinafter referred to

- New vehicles will eventually be equipped with emission controls, such as those required for partial zero emission vehicle (PZEV)[15] systems, that achieve zero evaporative standards for VOCs.

- Evaporative emissions from ethanol-blended fuel may be influenced by the effect of permeation through the vehicle fuel system. Permeation emissions were shown in recent studies to increase with 6 %ethanol blends (E-6) and E-10 compared to non-oxygenated fuel, especially at higher temperatures. The extent of increase varies substantially with vehicle design. The resulting impact on emissions inventories depends on the fraction of total evaporative emissions attributable to permeation, and cannot be quantified based on available data.

- The use of ethanol in gasoline does not cause the release of any new air toxics, but only increases or decreases the levels of contaminants already present in the atmosphere. The change in ambient concentrations is expected to be modest in that gasoline alone, without oxygenates, is already responsible for substantial evaporative and tailpipe emissions.

- Combustion of E-10 is expected to increase $NO_X$ emissions, as compared to both RFG without oxygenate and MTBE blends. Ozone production on high ozone days in Connecticut can be more dependent upon $NO_X$ than on VOC concentrations.

- Specific changes in atmospheric levels of air pollutants resulting from the changeover to ethanol-blended fuels cannot be quantified because the available data, mostly from studies in California, cannot be reliably extrapolated to Connecticut.

- Continued evaluation of VOC reduction strategies for off-road gasoline engines[16] will be necessary. Off-road sources constitute a significant portion of Connecticut's VOC emissions and there are federal limits on states' ability to regulate them.

- Passage of EPAct, which repealed the federal CAA oxygenate requirement nationwide, has eliminated the need for Connecticut to consider requesting a waiver from the oxygenate requirement in RFG.

- EPAct restricts states from adopting new "boutique fuels" programs. Any state requirement that expands, limits or prohibits the use of ethanol in RFG could constitute the creation of a new boutique fuel. Under EPAct there are hurdles that will be difficult to overcome; these must be considered in planning future strategies.

---

as: CRC Project No. E-67, January 30, 2006. (See summary presentation at: http://www.aqmd.gov/tao/ConferencesWorkshops/06_EthanolWS/04-TomDurbin_revised_background.pdf.) .

[14] EPA Renewable Fuel Standard Program Draft Regulatory Impact Analysis, September 2006, page 95 (citing CRC Project No. E-67, January 30, 2006). Hereinafter referred to as EPA Renewable Fuel Standard (September 2006).

[15] To qualify for PZEV credit, a vehicle must be certified to the super ultra low emission level exhaust standards, have zero evaporative emissions and have a 150,000-mile warranty for the performance of the emission control equipment. CARB, Staff Report: 2000 Zero Emission Vehicle Program, Biennial Review, August 7, 2000, page 5.

[16] Off-road gasoline engines include, but are not limited to, lawn mowers and other garden equipment, snow blowers and off-road recreational vehicles such as snowmobiles.

- Continued evaluation of emerging data is necessary to assess any changes in environmental quality potentially attributable to the use of ethanol as an additive in gasoline and should be considered during attainment planning. Studies currently underway may begin to resolve these issues. Connecticut should not consider a new research program until these studies have been published and evaluated.

- The continued use of ethanol-blended fuels has a number of benefits for Connecticut:
  - Ethanol is integral to reducing the state's dependence on fossil fuels; and
  - Ethanol reduces greenhouse gas emissions necessary to meet the goals of the Climate Change Action Plan by displacing 165 million gallons of gasoline.

## Historic Perspective on Ethanol Blended Fuels

What follows is a summary of the history and development of ethanol fuels emphasizing issues relevant to the study required by the Act. A more complete discussion is provided in a background article prepared by the American Petroleum Institute (API) and reproduced in Appendix 6 on page 50.[17]

### *The Clean Air Act and Reformulated Gasoline*

The 1990 Clean Air Act Amendments required federal fuel programs to be implemented in certain areas that do not meet National Ambient Air Quality Standards (NAAQS) for the criteria pollutants, carbon monoxide (CO) and ozone. These programs originally contained fuel specifications that required a minimum oxygen content, measured by weight percent, in the gasoline. Oxygenates reduce CO because they provide extra oxygen for more efficient combustion. While oxygenates were originally required as a control strategy for carbon monoxide, they had a corollary benefit of reducing toxic air pollutants and greenhouse gases (GHGs). Additionally, by decreasing the overall volume of petroleum products consumed, the use of oxygenates in fuel promotes renewable fuel resources such as ethanol. However, ethanol fuels can evaporate by permeating through the fuel systems of vehicles to release more VOCs into the air. In addition, the increased temperatures created by the efficient combustion may lead to increased production of $NO_X$. During combustion, nitrogen from the air reacts with oxygen from the fuel to produce $NO_X$. This is a concern because $NO_X$ reacts with VOCs in the presence of sunlight to create ozone, a criteria pollutant and a primary constituent of smog. Although the type of oxygenate required by these programs was not specified, MTBE was the initial oxygenate of choice among gasoline suppliers throughout most of the country, except in the Midwest.

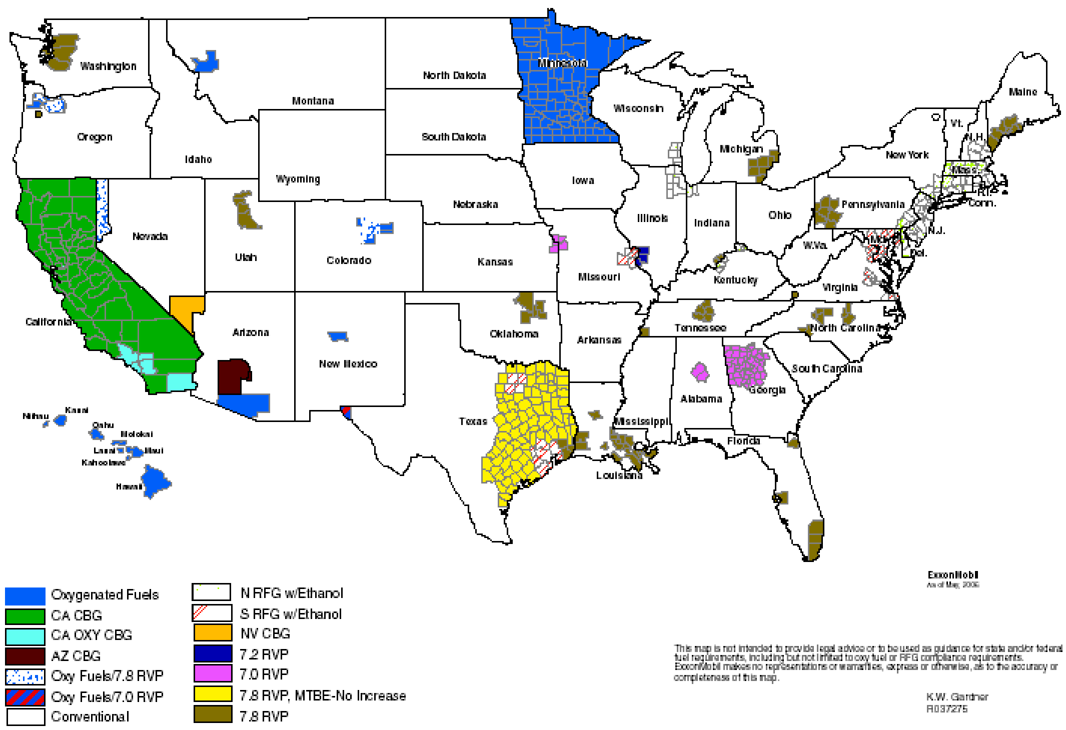
In the winter of 1992-1993, the federal wintertime oxygenated fuel program was implemented in two regions of Connecticut that did not meet NAAQS for carbon monoxide. This program, required only in the winter season, specified that gasoline contain a minimum oxygen content of 2.7% by weight. To meet this specification, oxygenated gasoline sold in Connecticut contained approximately 15 % MTBE, by volume. By the winter of 1999-2000, Connecticut was in

[17] API, Backgrounder on Low Level Gasoline Blends Containing Ethanol (Blends containing Ethanol at concentrations up to 10% by volume), May 12, 2006.

attainment for CO and this program was no longer required anywhere in the state to meet NAAQS for CO.

Starting in January 1995, Phase I of the federal RFG program was implemented in the entire state of Connecticut. This program was required in certain areas that do not meet NAAQS for ozone. Required year round, the Phase I reformulated gasoline program also specified that gasoline contain a minimum oxygen content of 2.0 %, by weight. To meet this specification, the oxygenated gasoline sold in Connecticut contained approximately 11 % MTBE, by volume, which is 2% oxygen by weight.

**Figure 2: U.S. Gasoline Standards 2006[18]**

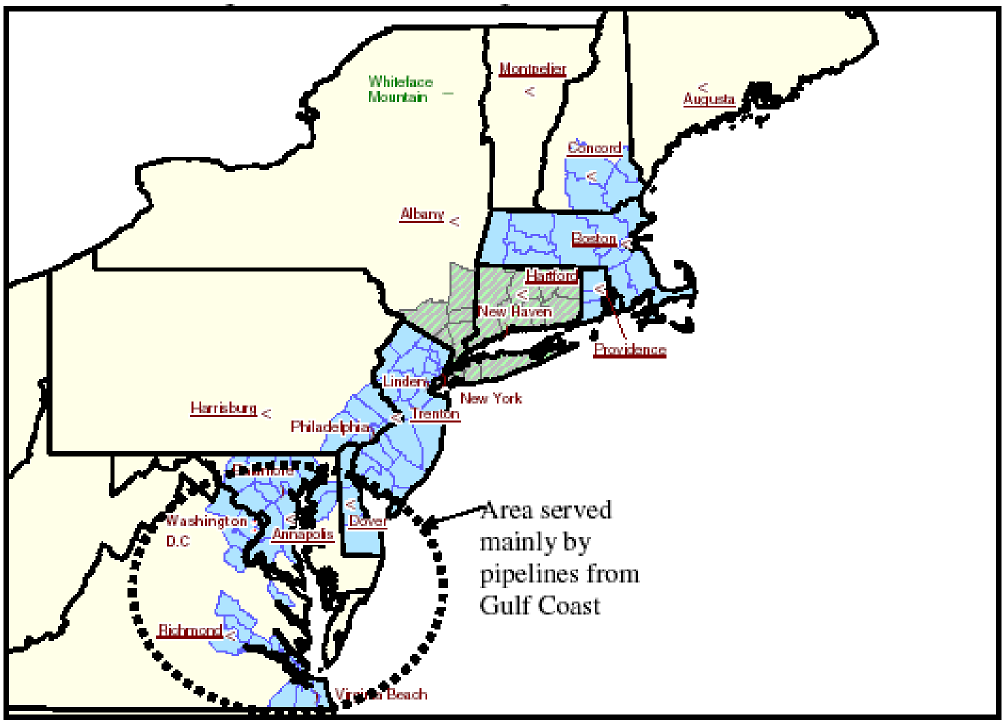



Phase II of the RFG program, with more stringent standards, was implemented in January 2000, in certain areas of continued non-compliance for the ozone standard. The Phase II program maintained the requirement that gasoline contain a minimum oxygen content of 2.0 %, by weight. Figures 2 and 3 show that ethanol blended RFG is currently used in all of Connecticut and a significant portion of the I-95 corridor in the Northeast. In addition to the ozone and CO limiting benefits, both phases of the RFG program also identified aggregate limits for emissions of the following specific mobile source air toxics: benzene, 1,3-butadiene, polycyclic organic matter, acetaldehyde and formaldehyde.

---

[18] National Petroleum Refiners Association, http://www.npra.org/issues/fuels/state_bb/us_fuels_map.pdf, prepared by ExxonMobil, May 2006. Note: This map is not intended to provide legal advice or to be used as guidance for state and/or federal fuel requirements, including but not limited to oxy fuel or RFG compliance requirements. ExxonMobil makes no representations or warranties, express or otherwise, as to the accuracy or completeness of this map.

**Figure 3: RFG-Consuming Areas on the East Coast**[19]




Legend: The shaded regions represent areas using RFG. New York and Connecticut RFG areas are shaded differently to represent a ban on MTBE.

### *The Banning of MTBE*

The use of MTBE as an oxygenate in fuel was very effective in reducing the emissions of CO and air toxics.[20] However, as the widespread use of MTBE in gasoline products led to decreases in air pollution emissions, the incidence of MTBE contamination of groundwater, including drinking water supplies, increased. This contamination was compounded by MTBE's mobility in groundwater.

These groundwater contamination concerns led Connecticut to join other states in enacting legislative bans on the use of MTBE in gasoline. On July 1, 2000, Public Act 00-175, now codified at Section 22a-450a of the General Statutes, was enacted. This act effectively banned the sale and use of MTBE as a gasoline additive in Connecticut, and required that the DEP develop a plan to implement the ban in Connecticut. Subsequent amendments to the law changed the effective date of the ban of MTBE as a gasoline additive to January 1, 2004. In preparation for this transition, DEP submitted several annual reports to the General Assembly addressing groundwater and other environmental concerns, infrastructure and other costs, and progress in implementing Connecticut's legislative ban. These can be found on the DEP website

---

[19] EPA, RFG Consuming Areas on the East Coast, http://www.epa.gov/otaq/regs/fuels/rfg/rfgarea.pdf. **Note:** EPA lists as an RFG opt-in region the area of Whiteface Mountain that lies above 4,500 feet in elevation. This area is in Essex County, but is not shaded on the map.

[20] Connecticut DEP, MTBE webpage at http://www.dep.state.ct.us/air2/mtbe/index.htm.

at http://www.dep.state.ct.us/air2/mtbe/index.htm. As shown in Figure 4, twenty-nine[21] states have similar MTBE bans that are either in effect or pending.

**Figure 4: States with MTBE Bans[22,23]**


The ban of MTBE created a de facto requirement that fuel sold in Connecticut contain ethanol, since ethanol was the only oxygenate available to meet the volume requirements of the oxygen mandate under the Clean Air Act. Distributors and retailers made significant investments in infrastructure associated with the changeover. This was necessary, in part, because ethanol is easily contaminated by water and cannot be transported via pipelines; it must be transported by rail or truck and blended at the distribution site.

To maintain compliance with federal regulations for air toxics and Reid Vapor Pressure (RVP), refiners were required to make adjustments to their gasoline blendstocks. The RVP of the

---

[21] Contrary to what is indicated on the map, Massachusetts has no plans to enact an MTBE ban. Massachusetts Department of Environmental Protection, personal communication 11/29/06.

[22] Status: 2006: **ACE's State-by-State Ethanol Handbook** A 50-state guide to the U.S. ethanol industry, page 56.

[23] Dark brown states have enacted MTBE bans; gray states are considering MTBE bans. (Massachusetts has no plans to enact an MTBE ban. Massachusetts Department of Environmental Protection, personal communication 11/29/06.)

modified blendstocks, referred to as reformulated gasoline blendstock for oxygenate blending (RBOB), were lowered in order to compensate for the 1.0 pound per square inch (psi) RVP increase resulting from the addition of ethanol. Ethanol blended into gasoline at only 5.6% by volume complies with the 2.0% by weight oxygen requirement, but refiners elected to blend ethanol at 10% by volume in order to maximize federal tax benefits. California capped the percentage of ethanol permissible in gasoline sold in their state at 5.7% by volume. Gasoline blended for use in Connecticut remains at 10%, as is that for other RFG states with MTBE bans listed in Table 1.

**Table 1: Ethanol Concentrations in RFG Blends for States with MTBE Bans[24]**

| RFG States with MTBE Bans | Gasoline Blends with ≥5.7% Ethanol |
|---|---|
| California | 5.7% |
| Connecticut | 10% |
| Illinois/Indiana (partial) | 10% |
| Kentucky (partial) | 10% |
| Missouri (partial) | 10% |
| New York (partial, statewide MTBE ban) | 10% |
| Wisconsin (partial) | 10% |
| New Hampshire (partial) | 10% |
| Rhode Island | 10% |

***Connecticut's Oxygenate Waiver Request and the Energy Policy Act***

## Oxygenate Waiver

Prior to the enactment of the statutory ban on MTBE, DEP submitted a request for a waiver from the oxygenate requirement to EPA under Section 211(c) of the Clean Air Act. DEP's waiver request was based on an analysis that the use of ethanol as an oxygenate increased the volatility of the fuel blend leading to increased emissions of VOCs. This increase in VOC emissions was one of the factors interfering with Connecticut's ability to reach attainment with the ozone NAAQS. The DEP asserted that the federal oxygenate requirement was not protective of public health and the environment and could lead to increased costs. EPA denied Connecticut's waiver request and the similar requests submitted by the states of California and New York. Several states continued to press the issue nationally until congressional action was taken with the passage of EPAct in 2005. EPAct repealed the requirement that RFG contain 2.0% oxygen by weight effective on May 6, 2006, and has eliminated the need for Connecticut to continue to pursue its request for a waiver from the oxygenate requirement in RFG. The correspondence associated with this process and EPA's eventual denial of the request can be found on the DEP website at http://www.dep.state.ct.us/air2/fuels/index.htm.

[24] Data extracted from: EPA, RFG Properties Survey Data: Information on Reformulated Gasoline (RFG) Properties and Emissions Performance by Area and Season, ***http://www.epa.gov/otaq/regs/fuels/rfg/properf/rfgperf.htm***.

**The Environmental Policy Act of 2005**

EPAct created a nationwide renewable fuel standard (RFS) that stipulates that specific quantities of fuel sold must be from renewable sources. In December of 2005, EPA adopted the default national standard set forth in the EPAct for 2.78%, or 4.0 billion gallons, of fuel sold in 2006 to be from renewable sources. EPA has proposed rulemaking to adopt the default national standard of 3.71 %, or 4.7 billion gallons of fuel for 2007. These EPAct quantities of renewable fuel increase to 7.5 billion gallons in 2012. Ethanol is expected to be a significant portion of this projection.

In an effort to limit the number of fuel blends nationally, EPAct restricts states from adopting new "boutique fuels" programs. EPAct provisions effectively preempt states from adopting new fuel options not already approved by EPA; these restrictions must be considered in developing future fuel strategies. EPAct established a strictly limited list of approved fuel blends, or boutique fuels, for use in RFG states. No new boutique fuels can be added to that list unless an approved fuel is withdrawn; and replacement is limited by regional fuel uses. Any state requirement that expands, limits or prohibits the use of ethanol in RFG could constitute the creation of a new boutique fuel. Under EPAct, as currently interpreted, Connecticut cannot implement fuel requirements that would result in the creation of a new boutique fuel.

Inspired, in part, by EPAct, a number of states have implemented programs to provide incentives for the manufacture of ethanol and the sale of ethanol fuels. In Connecticut, Governor Rell's proposed energy plan sets goals for increasing the use of renewable resources and alternative fuels while reducing fossil fuel consumption. New York is providing incentives for the construction of a new $87 million ethanol production plant at the former Seneca Army Depot in Romulus, NY, which will be able to produce 50 million gallons of ethanol per year; the plant will be eligible to receive a state production tax credit of up to $2.5 million per year. This follows similar efforts in a number of midwestern states. A summary of state ethanol fuel incentive programs appears in Appendix 7 on page 67.

## Health Impacts Analysis

In response to the Public Act 06-53, the DPH has reviewed the potential consequences of ethanol's use in gasoline on air and groundwater quality, and the ways in which these changes may affect human health. DPH's review is based upon information provided by DEP as well as on assessment of published literature conducted independently by DPH. DPH previously analyzed the risks from drinking groundwater affected by gasoline spills that carry ethanol to potable wells. That analysis was part of a report prepared by the NEIWPCC and NESCAUM;[25] a summary of the report's recommendations appears in Appendix 5 of this report on page 49.

The main focus of the current DPH review and analysis is the potential for ethanol, at its current volume composition in gasoline in Connecticut (10%), to:

1. Cause the release of unique toxic chemicals into the atmosphere or groundwater;

[25] NEIWPCC/NESCAUM (2001).

2. Increase or decrease the release of existing toxic chemicals into these media; and
3. Increase or decrease public health risks associated with the use of gasoline in Connecticut.

***Air Quality Impacts: Evaporative Emissions***

**Potential Influence on VOC Evaporative Emissions**

Gasoline is a highly volatile mixture from which numerous ingredients can evaporate, going from the liquid to the gaseous state at typical temperatures. Evaporative emissions can result from leaks in the fuel system and venting mechanisms; new technologies available on LEV II program vehicles can control these sources of pollution. However, evaporative emissions can also result from permeation through a vehicle's intact fuel system, a mechanism that is not fully understood. Evaporative emissions are a potential public health concern due to their contribution to air toxics and the formation of ozone. These evaporative emissions put a wide range of VOCs into the air, some of which are particularly toxic, but all of which can contribute to the level of VOCs in the atmosphere. Since VOCs are a key ingredient in the formation of summertime ozone, it would follow that the more VOCs emitted from vehicles, the greater the chances to exceed the ozone NAAQS in Connecticut. However, ozone formation is a complex process and heavily dependent on both meteorological conditions and the transport of precursors from upwind areas such as New York City. Furthermore, on the highest ozone days, the amount of ozone in Connecticut is more dependent on $NO_X$ levels. This is due to the disproportionate VOC releases from natural sources, such as trees, on high temperature days, a phenomenon which overwhelms man-made sources of VOCs.

Ethanol, when blended into gasoline, increases the volatility of the mixture. At a concentration of 10% in the gasoline, ethanol adds about one pound per square inch (1 psi) of volatility (also known as Reid Vapor Pressure or RVP). This increase is on the order of 10-15% over the base gasoline and also represents an increase in RVP over MTBE-blended gasoline. Because of this added volatility and release of ozone precursors, the gasoline blendstock in Connecticut is modified to reduce RVP in order to compensate for the volatility increase. When blended with 10% ethanol, the fuel has an RVP that is under the EPA RVP limit for high ozone areas of 7 psi. Thus, the addition of ethanol to gasoline in Connecticut does not lead to excessive volatility and VOC emissions, at least not in relation to RVP.

However, ethanol may increase evaporative emissions by enhancing permeation of the fuel through intact hoses, seals and, if it is not metal, the gas tank itself. Ethanol is highly soluble in a variety of materials, a property which allows it to penetrate into and through the materials; it then offgases into the air on the other side. This appears to correlate with increased permeation of other VOCs in gasoline across these materials. Two recent studies by the Coordinating Research Council (CRC), a research institute organized by the automotive and fuels industries, prepared for the California Air Resources Board (CARB) have examined this aspect of gasoline vapor escape from vehicle fuel systems.[26,27] The initial report evaluated fuel permeation at

[26] CRC (Coordinating Research Council), Fuel Permeation from Automotive Systems. CRC Project No. E-65, 2004.
[27] CRC Project No. E-65-3, August 2006.

elevated temperatures from intact fuel systems across ten different vehicle models.[28] Each vehicle fuel system was then assigned a fuel test rig number (1 through 10) and each was tested with three gasoline blends. The testing included one fuel blend containing no oxygenate, another containing 5.7% ethanol, and another with no ethanol but 11% MTBE. As a follow-up to this report, the CRC conducted further permeation studies that expanded upon the initial work by varying the percentage of ethanol and aromatics in gasoline and tested their permeation rates on five different fuel system test rigs.[29] The follow-up studies carried forward two fuel test rigs from the initial study and also introduce and tested newer automotive fuel systems.

It is important to emphasize that while these studies used ethanol and MTBE-blended gasolines at concentrations comparable to the ethanol and MTBE levels used in Connecticut, there are other formulation differences between fuel blends in California and the Northeast that decrease the ability to extrapolate test results to Connecticut. The most significant of these are climate-dependent parameters which stabilize the evaporative characteristics over climate conditions that vary from season to season and from region to region. Fuels blended for New England summers will be different from those blended for summertime in California and the winter gasoline blends for each climate will be different from each other as well as from the summer blends.

Permeation testing found that ethanol increased fuel evaporative emissions, relative to both the baseline fuel with no oxygenate and MTBE blends. The increases were several hundred milligrams (mg, 1/1000 of a gram) to nearly three grams (g) of VOCs/day. The contribution of permeation to the overall emission rate of VOCs from gas tanks and vehicle engines is not well understood for the current vehicle fleet. Research presently underway by CRC seeks to quantify the contribution of permeation, as well as venting and leakage, to total evaporative emissions. Preliminary results of this research are expected to be released early in 2007. As discussed above, the increase in gasoline vapor release due to ethanol via non-permeation mechanisms is countered by lowering the RVP of the base gas. Therefore, the recent permeation studies by CRC suggesting that ethanol can promote VOC emissions from intact fuel systems, represent the increase in ethanol evaporative emissions from the one remaining emission pathway of permeation. Additional research is necessary to determine the relative contribution of this permeation pathway to overall evaporative emissions.

Earlier modeling of the effect of ethanol in gasoline on evaporative emissions of VOCs was provided in a report issued by the CARB and California EPA.[30] While total VOC emissions were not presented, airborne levels of a representative and highly toxic VOC from gasoline, benzene, were estimated and are shown in the table in Appendix 8 on page 69.[31] CARB/CalEPA estimated that there was no increase in airborne benzene from California 10% ethanol gasoline relative to the California 11% MTBE gasoline. However, it was estimated that there was an increase in airborne benzene of 7% when going from the California base gasoline without oxygenate, to the California 10% ethanol blend. The lack of change in benzene in

[28] The fuel systems from the 10 vehicles were removed without disassembly and attached to test rigs.
[29] Test rigs 1 and 2 from the initial studies were utilized in the follow-up study.
[30] California Air Resources Board & California EPA, Office of Environmental Health Hazard Assessment, Health and Environmental Assessment of the Use of Ethanol as a Fuel Oxygenate, (1999), http://www-erd.llnl.gov/ethanol/etohdoc/vol3/vol3.pdf. Hereinafter referred to as CARB/CalEPA (1999).
[31] Reprinted from the CARB/CalEPA (1999) report. See Appendix 8, page 69.

association with ethanol is in part due to compensatory factors: ethanol promotes greater permeation and evaporation of the fuel to the atmosphere, while also replacing some of the VOCs by virtue of its presence in gasoline at a content of 10%. These factors act in opposite directions to lead to little or no change in predicted benzene concentration while slight increases in overall VOC releases. These estimates need to be updated to incorporate the latest permeation test data and new studies referenced above, which are probing the relative importance of different evaporative emission pathways.

All of the studies cited have involved ethanol-blended fuels in on-road vehicles. There is little research that deals specifically with evaporative emissions from ethanol fuels used in engines for off-road uses such as lawn mowers and other gasoline powered garden equipment, snow blowers and off-road recreational vehicles. Some studies have been described in CARB reports associated with rule making to cover off-road equipment.[32] Significantly, as early as 1995, EPA noted the potential for ethanol RFG to cause leakage from the gaskets of non-road engines.[33] The fuel systems for these engines may not have been designed for use with ethanol and permeation from them is expected to be an issue. Federal law, however, prohibits states outside California from regulating engines less than 50 horsepower until after EPA has established regulations for them.[34] Even if substantial research existed to quantify permeation emissions from these small engines, Connecticut would be unable to regulate them at this time.

**Potential Influence on Atmospheric Ethanol Levels**

In the absence of evaporative emission controls, the addition of ethanol to gasoline leads to increases in the ambient concentration of ethanol. The CARB/CalEPA risk assessment[35] estimates that in Southern California, the background atmospheric ethanol, without the addition of ethanol blended fuel, would be 5.1 parts per billion (ppb) (see the 2003, Non-Oxy column in Appendix 8 table). This is expected to increase to 8.8 ppb due to 3.5% oxygen.[36] This 73% increase in modeled atmospheric ethanol is not a health concern given the small dose of ethanol this represents. The daily dose of ethanol to a pregnant women from inhaling 8.8 ppb (assuming 20 cubic meters ($m^3$) air inhalation/day) is:

8.8 ppb = 16.6 micrograms per cubic meter ($\mu g/m^3$)
Ethanol dose = 16.6 $\mu g/m^3$ * 20 $m^3/d$ = 331 $\mu g$ or 0.3 mg ethanol per day

The amount of ethanol in a typical alcoholic beverage is 12 g. Thus, the amount one could inhale, 0.3 mg/day is 40,000 times less than one drink per day. That is a trivial exposure, much too low to be of risk concern, even to the most sensitive human receptor, a pregnant woman.

---

[32] CARB, Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Public Hearing to Consider the Adoption of Exhaust and Evaporative Emission Control Requirements for small Off-Road Equipment and Engines Less Than or Equal to 19 Kilowatts, August 8, 2003. http://www.arb.ca.gov/regact/sore03/isor.pdf
[33] EPA, Use of Reformulated Gasoline in Nonroad Engines (EPA 420-F-95-007, April 1995).
[34] The Consolidated Appropriations Act of 2004 (HR 2673, Section 428): States are prohibited from adopting or attempting to enforce regulations of *spark ignition engines* smaller than 50 horsepower until after model regulations have been promulgated by EPA. There is an exception for California and for other states that had adopted regulations for small engines prior to September 1, 2003.
[35] CARB/CalEPA (1999)
[36] Note: Et3.5% column: 3.5% oxygen content equates to 10% ethanol by volume.

Pregnant woman are advised to avoid alcohol during pregnancy; the American Academy of Pediatrics states, "Because there is no known safe amount of alcohol consumption during pregnancy, the Academy recommends abstinence from alcohol for women who are pregnant or who are planning a pregnancy."[37] The amount possible from the atmosphere, one 40,000$^{th}$ (1/40,000) of a drink, is even less than the amount of ethanol in the human diet from ripe fruit. For example, the allowable limit of ethanol from natural sources in fruit juice is 0.3%. If one drank an eight-ounce glass of orange juice, that could theoretically deliver 0.72 g of ethanol, more than 2000 times the atmospheric dose calculated above. It is also noteworthy that the majority of the atmospheric dose is from background sources and not from the ethanol added to gasoline.[38]

There are no ambient monitoring data from the United States, outside of California, to confirm the CARB/CalEPA estimate of airborne ethanol; however, the estimates are consistent with data from Brazil. Porto Allegre is a Brazilian city in which 17% of the vehicles run on 100% ethanol; airborne ethanol measurements in that city, between March of 1996 and April of 1997, averaged 12 ppb.[39]

***Air Quality Impacts: Tailpipe Emissions***

It was previously assumed that exhaust emissions from Tier 1[40] and newer low emission vehicles would not vary as a function of climate-dependent fuel parameters. However, a recent CRC study,[41] acknowledged by EPA,[42] reports exhaust emissions data that suggest Tier 1 vehicles are, in fact, sensitive to climate-related evaporative fuel parameters in ethanol blended gasolines. As has been discussed previously, the CRC studies were done for CARB under California climate conditions, using California fuel blends. Because of the differences between ethanol fuels blended for California and Connecticut, the results reported in the CRC exhaust emissions report may not accurately predict the change in Connecticut vehicle emissions resulting from the transition to ethanol. However, these studies provide the most robust data from which to discuss possible air quality impacts in Connecticut.

The presence of an oxygenate in gasoline can be expected to increase certain tailpipe emissions and decrease others.[43] Oxygenates facilitate a more complete combustion of the fuel which should decrease incomplete combustion products of toxicologic concern such as 1,3-butadiene. However, the additional oxygen in gasoline promotes the formation of $NO_X$, primarily $NO_2$, which are key atmospheric reactants in the formation of ozone. When ethanol is the oxygenate,

---

[37] AMERICAN ACADEMY OF PEDIATRICS: Fetal Alcohol Syndrome and Alcohol-Related Neurodevelopmental Disorders, PEDIATRICS Vol. 106 No. 2, August 2000, pp. 358-361.
[38] CARB/CalEPA (1999)
[39] Grosjean, D., Grosjean, E., Gunawardena, R., Rasmussen, R.A., *Ambient Concentrations of Ethanol and Methyl tert-Butyl Ether in Porto Alegre, Brazil, March 1996-April 1997*, Environmental Science & Technology, Vol. 32, 1998, pp. 736-742. Hereinafter referred to as Grosjean (1999)
[40] Exhaust emission standards and implementation schedules for Tier 1 vehicles can be found on the EPA website under "Federal and California Exhaust and Evaporative Emission Standards for Light-Duty Vehicles and Light-Duty Trucks," http://www.epa.gov/otaq/stds-ld.htm.
[41] CRC Project No. E-67, January 30, 2006.
[42] EPA Renewable Fuel Standard (September 2006).
[43] HEI (Health Effects Institute), The Potential Health Effects of Oxygenates Added to Gasoline: A Review of the Current Literature, (1996).

one can expect increased tailpipe emissions of acetaldehyde as it is the product of ethanol oxidation. To some extent, the increase in acetaldehyde emissions is compensated for by a decrease in formaldehyde that was emitted when MTBE was used as the oxygenate. Formaldehyde is more acutely toxic and carcinogenic than acetaldehyde. Finally, the exhaust emission of the irritant gas, peroxyacetylnitrate (PAN) can be increased as it is also formed from the oxidation of ethanol.

The potential impacts of ethanol-containing gasoline on these tailpipe emissions have been evaluated in studies of individual vehicles under running, but stationary, conditions, in models which simulate the exhaust emissions and their fate in the atmosphere, and by evaluating atmospheric measurements of these pollutants pre- and post-conversion to ethanol-containing gasoline. It should be noted that the study of air toxics in the 2006 CRC exhaust emissions report,[44] on which some of the following discussion is based, used fuels which are different from blends used in Connecticut due to the climate-related parameters discussed previously. The following sections briefly summarize the expected trends in tailpipe emissions associated with ethanol use projected from data collected for gasolines blended for and tested in California.

**Acetaldehyde:** Acetaldehyde is a carbonyl compound that is an irritant and toxic gas which can cause symptoms, possibly including asthmatic reactions, at concentrations as low as 25 ppm (45,100 ug/m$^3$).[45] It is also a theoretical risk for cancer of the nose from long-term inhalation exposure to 3 ug/m$^3$ and above. It is approximately ten times less potent than formaldehyde in producing respiratory irritation and cancer.[46] Increased emissions in this aldehyde are the most direct result of ethanol use in gasoline, as it is formed from the oxidation of ethanol. Acetaldehyde is a component of direct or primary exhaust emissions. It can also be formed in the atmosphere as a result of photochemical reactions in a process termed secondary formation. This secondary formation generally is the overwhelming contributor to atmospheric acetaldehyde concentration and thereby decreases the significance of the primary emissions. Several studies have been conducted indicating that an increase in atmospheric acetaldehyde concentrations may occur; however, since a substantial uncertainty exists regarding these studies, based on available data, it is not possible to reliably estimate the impact, if any, on ambient acetaldehyde concentrations that may accompany the change to E-10 in Connecticut. Since ambient concentrations depend strongly on meteorological conditions as well as the relative concentrations of numerous precursors, the ratio of direct emissions to total ambient acetaldehyde may vary significantly from one location to another. In addition, since biogenic, or naturally occurring, sources may be a significant contributor to overall ambient concentrations during summer months, the impact of man-made or anthropogenic emissions on the total inventory may vary considerably by season.

The limited data that exist for exhaust emissions of acetaldehyde from ethanol blends are based on a comparison of a particular blend of E-10 with a non-oxygenated fuel, each of which differ from the reformulated gasoline sold in Connecticut. While these data suggest that direct exhaust emissions of acetaldehyde are likely to increase with the use of E-10 fuel, detailed state-specific precursor inventories, as well as meteorological and emissions and monitoring data, would need

[44] CRC Project No. E-67, January 30, 2006.
[45] ACGIH (American Council of Governmental Industrial Hygienists), Documentation of the TLVs, (1991).
[46] Ibid.

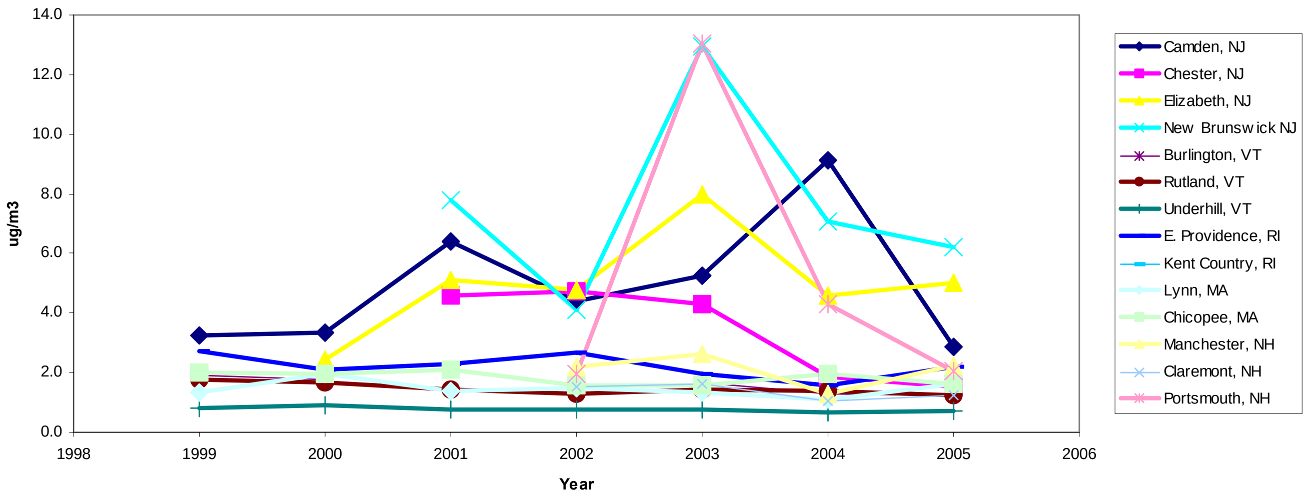
to be obtained in order to reliably estimate the impact on overall ambient concentrations of acetaldehyde through modeling. Obtaining such detailed information is beyond the scope of this report.

The exhaust emissions study from the Coordinating Research Council[47] evaluated the effect of ethanol in gasoline on exhaust emissions. A matrix of gasoline blends was tested in a variety of different vehicle models sold in California. The average increase in acetaldehyde tailpipe emission due to 10% ethanol was doubled relative to baseline gasoline with no oxygenate. In 1999, CARB/CalEPA[48] conducted ambient modeling based upon the CRC exhaust emissions data that showed acetaldehyde emission could increase by a factor of two with the addition of ethanol to gasoline. The modeling results estimated the doubling in emission rate would only result in a 12% increase in acetaldehyde levels in the atmosphere. This is due to the fact that acetaldehyde is a common air pollutant, being generated by a number of different sources. Therefore, the increase from ethanol in gasoline should not have a large impact on its levels in air. Actual measurements of acetaldehyde in locations where ethanol is a major component of gasoline seem to bear this out.[49] For example, measurements in Denver, Colorado could not detect any increase in acetaldehyde as a result of the switch to ethanol-containing gasoline. The only evidence for an increase is in Brazil where ethanol is present in gasoline at considerably higher concentrations than 10%, with many vehicles running on 100% ethanol. Acetaldehyde concentrations measured in Brazilian cities are among the highest in the world (30-40 ppb),[50] well above the CARB/CalEPA estimates presented in Appendix 8 for Southern California.

Connecticut DEP measurements of acetaldehyde from a monitoring station in East Hartford found average summertime levels of 1.15 ppb in 2003, the summer before conversion of Connecticut fuel from MTBE to ethanol. The East Hartford average concentration for the summer of 2005 was 25% higher (1.43 ppb). This is consistent with the model results from CARB/CalEPA (1999) and suggests only a small increase in ambient acetaldehyde due to ethanol addition to gasoline. As illustrated in Figure 5, these numbers are consistent with those found elsewhere in New England.[51]

[47] CRC Project No. E-67, January 30, 2006.
[48] CARB/CalEPA, (1999).
[49] CARB/CalEPA, (1999).
[50] Grosjean (1999)
[51] NESCAUM. East Hartford values are converted to 2.07 μg/m$^3$ for 2001 and 2.58 μg/m$^3$ for 2005.

**Figure 5:**
**Trend in Acetaldehyde Concentrations 1999-2005**
*prepared by NESCAUM*




The measured levels of acetaldehyde in East Hartford are approximately 20,000 times below the level at which irritation effects begin to occur in humans and so ambient acetaldehyde is not expected to be an important contributor to acute irritation or asthma in Connecticut. The measured concentrations are just below the minimum exposure level for cancer risk concerns (3 $ug/m^3$ or 1.65 ppb) and so the additional acetaldehyde generated by tailpipe emissions from 10% ethanol blends is not a significant contributor to cancer risk.

A small segment of the population, primarily of Asian descent, has a genetic variation which renders the enzyme aldehyde dehydrogenase-2 (ALDH-2) inactive.[52] The susceptible gene variant occurs at an incidence of approximately 5% in the homozygous form, causing both gene copies to be the susceptible variant and leading to no ALDH-2 activity. This could lead to a significant increase in sensitivity to acetaldehyde's toxic and carcinogenic effects.[53] However, these conclusions are based upon studies of ethanol ingestion where the blood level of acetaldehyde is high. In contrast, the baseline levels of acetaldehyde in the atmosphere and the small increase possible due to ethanol in gasoline are very low, so low in fact that alternative metabolic pathways are available to detoxify absorbed acetaldehyde.[54] Therefore, atmospheric acetaldehyde is not expected to be a risk factor even for this more highly susceptible subpopulation.

**Formaldehyde**: Formaldehdye is similar to acetaldehyde in its spectrum of toxic effects when inhaled including irritation and cancer, primarily of the nasal cavity. The difference is that

---

[52] Vasiliou, V. and Pappa, A., Polymorphisms of human aldehyde dehydrogenases. *Pharmacology*, 2000, **61:** 192-198.
[53] Ginsberg, G, Smolenski, S, Hattis, D and Sonawane, B, Population distribution of aldehyde dehydrogenase-2 genetic polymorphism: implications for risk assessment. Regulatory Toxicol Pharmacol, (2002), Vol. 36: 297-309.
[54] Kunitoh, S, Imaoka, S, Hiroi, T, Yabusaki, Y, Monna, T and Funae, Y. Acetaldehyde as well as ethanol are metabolized by human CYP2E1. J Pharmacol Exper Ther , 1997, Vol. 280, pp. 527-532.

formaldehyde is considerably more toxic. Formaldehyde is in the exhaust from baseline gasoline and this emission increases when MTBE is present because the methyl group in MTBE can oxidize to formaldehyde. Therefore, replacement of MTBE with ethanol can be expected to decrease formaldehyde emissions. The modeled estimates from California, shown in Appendix 8, suggest that only a slight reduction in formaldehyde can be expected due to MTBE removal from the 2003 blend of gasoline in California. Therefore, if ethanol replacement of MTBE does lower ambient formaldehyde, it is not expected to be by a substantial amount.

**Peroxyacetyl nitrate (PAN)**: This irritant gas is also normally present in the exhaust from non-oxygenated gasoline but could theoretically increase due to ethanol. PAN is an atmospheric storage depot of nitrogen oxides and, like these oxides, can promote the formation of ozone. It can produce eye and respiratory tract irritation in humans at concentrations as low as 0.1-1 ppm (100-1000 ppb). As shown in Appendix 8, CARB/CalEPA modeling suggests a slight increase in atmospheric PAN due to ethanol in gasoline. This is not a health risk given that the PAN levels with or without ethanol are in the range of 5 ppb, which is 20 to 200 times below the level that might cause an acute irritant effect from PAN.

**1,3-Butadiene**: This carcinogenic gas is present in vehicle exhaust from the incomplete combustion of the hydrocarbons in gasoline. While its levels might theoretically be expected to decrease by an oxygenate that facilitates a more complete combustion, modeling results from CARB/Cal EPA suggest no difference across the 2000 California fuel blends, some of which have ethanol, and others which have MTBE or are non-oxygenated (Appendix 8). Therefore, it is unlikely that ethanol would produce much lowering of 1,3-butadiene emissions

**Nitrogen Oxides**: Increasing the oxygen content of gasoline is expected to increase tailpipe emissions of $NO_X$. CRC's 2006 exhaust emissions study[55] measured $NO_X$ emissions associated with various California gasoline blends and found as much as a 12% increase in emission when going from 0% to 10% ethanol. However, this was not a consistent finding across blends; fuels having lower volatility did not demonstrate the ethanol effect on $NO_X$. Comparison of the two fuels that most closely match gasoline sold in Connecticut revealed the potential for a 3.3% increase in $NO_X$ emission when going from 0% to 10% ethanol. CARB/CalEPA modeling of ethanol impact on ambient $NO_X$ found no change due to ethanol when comparing across the 2003 oxy- vs. non-oxy-fuel options (Appendix 8). Further, ambient monitoring in Connecticut at the East Hartford station found no increase in average summertime $NO_X$ levels between 2003, when MTBE was the predominant oxygenate, and 2005, when ethanol was used as the oxygenate; in fact there was a 27% decrease between these summers. This may be attributable to a variety of $NO_X$ reduction initiatives, regulatory and otherwise, during that time frame, that were independent of the oxygenate switch to ethanol.

**Volatile Organic Compounds:** Robust data are not available to compare potential emissions between RFG without ethanol and E-10 fuel in Connecticut. Thus, reliable estimates cannot be generated for the effect of ethanol-blended fuel on Connecticut's air quality from VOC emissions. However, recent and ongoing studies in California suggest that the use of E-10 may result in increases in both exhaust and evaporative emissions when compared to the use of non-oxygenated or MTBE-blended fuel. In these studies, the newer vehicles were shown to have

[55] CRC Project No. E-67, January 30, 2006.

fewer evaporative emissions and this trend is expected to increase in the future with turnover of the existing fleet of vehicles to newer models. The CRC exhaust emissions study found the potential for a 6.3% decrease in non-methane hydrocarbons, which include VOCs, when going from 0% to 10% ethanol. State-specific climate data and inventories of vehicles[56] would need to be obtained and evaluated, in order to estimate the effects of ethanol use on VOC emissions and air quality in Connecticut.

**Greenhouse Gases:** The addition of oxygenates to gasoline not only reduces the production of CO, it also decreases the production of the greenhouse gas, carbon dioxide. While other air pollution issues have since been identified, oxygenated fuels continue to be effective in reducing GHG emissions. Use of gasoline blended with 10% ethanol in Connecticut displaced approximately 165 million gallons of gasoline last year. It is generally accepted that a gallon of ethanol produces up to 20% fewer GHG emissions than a gallon of gasoline.[57] Therefore, the gasoline displacement in 2005 may have resulted in a reduction of as much as 293,000 tons of GHG. This is equivalent to removing up to 33,000 cars from Connecticut's highways.[58] While these benefits have been offset by the increases in vehicles in Connecticut, the use of E-10 in Connecticut has a positive benefit in meeting the goals of the Climate Change Action Plan of 2005.[59]

### *Possible Impacts on Summertime Ozone Levels*

As described above, the addition of ethanol to gasoline has the potential to increase summertime ozone levels due to its tendency to increase VOC permeation and $NO_X$ exhaust emissions from motor vehicles. Since VOCs are a key ingredient in the formation of summertime ozone, it would follow that the more VOCs emitted from vehicles, the greater the chances to exceed the ozone NAAQS in Connecticut. However, ozone formation is a complex process and heavily dependent on both meteorological conditions and the transport of precursors from upwind areas such as New York City. Furthermore, on the highest ozone days, the amount of ozone in Connecticut is more dependent on $NO_X$ levels. This is due to the disproportionate VOC releases from natural sources, such as trees, on high temperature days, a phenomenon that overwhelms man-made sources of VOCs.

$NO_X$ emissions, as discussed previously, are expected to increase with the replacement of MTBE blends with E-10 due to the increased availability of oxygen molecules and the higher temperatures of combustion. Summertime ambient air monitoring in Connecticut has failed to confirm this. In California, where the production of ozone is driven by $NO_X$ emissions year-round, a 5.7% cap on ethanol concentrations has been established by regulation. This concentration met the minimum for RFG that had been established under the CAA, but does not provide the energy independence benefit of E-10, which displaces 10% of gasoline. EPAct

[56] A full inventory that would more thoroughly account for VOC emissions should include off-road gasoline engines such as lawn mowers, snow blowers, etc.
[57] American Coalition for Ethanol, "Environmental & Clean Air Benefits," http://www.ethanol.org/environment.html.
[58] DEP, Motor Vehicle Related Greenhouse Gas Emissions in Connecticut, A Report Pursuant to Public Act 06-161, December 2006.
[59]Public Act 04-252, *Connecticut Climate Change Action Plan 2005*

limits on new boutique fuels restrict other states from requiring lower ethanol concentration in their fuel.
Research funded by California[60] resulted in the publication of an incremental scale, the Maximum Incremental Reactivity (MIR), that ranks the relative ability of chemicals to produce ozone. The MIR for ethanol is 1.88 g ozone per gram VOC, while the MIR for the base fuel averages 3-4 g ozone/gram VOC.[61] In a related research report, the National Research Council,[62] found the MIR of vehicle exhaust from vehicles that burned fuel oxygenated with ethanol to be slightly lower than vehicles that burned fuel oxygenated with MTBE. The results of these studies, in combination with the recent determination that emissions from newer vehicles are sensitive to climate-related fuel parameters, supports the conclusion that the determination of ethanol's contribution to ozone levels would be a multi-factor analyses requiring a significant investment.

The potential identification an ethanol impact from a review of Connecticut ambient ozone levels in the summers of 2003 through 2005, is confounded by the fact that ozone levels are highly dependent upon factors such as temperature and predominate wind direction as noted above. Results from a limited number of summers, in this case, three, are insufficient to show a trend in ozone because of variations in emissions of ozone precursors. Therefore, the ultimate effect of ethanol-blended gasoline on summertime ozone remains somewhat uncertain.

***Groundwater Releases***

Contamination of groundwater by gasoline components from leaking storage tanks, transportation accidents and other types of spills will likely continue to occur in spite of efforts to minimize these incidents. In the recent past this issue was exacerbated by the addition of MTBE to gasoline because of its persistence and mobility in groundwater. Replacement of MTBE with ethanol to meet minimum oxygen requirements for gasoline was intended to eliminate the groundwater contamination concerns raised by MTBE. The NEIWPCC/NESCAUM and CARB/CalEPA reports[63,64] review the potential for ethanol contamination of groundwater as a result of gasoline leaks and spills. These reports indicate that ethanol is much less likely than MTBE to contaminate potable wells because of the ethanol's rapid breakdown via biodegradation. Further, because ethanol is less toxic, it may be anticipated to have a substantially higher, risk-based, allowable drinking water level than MTBE (400 ppb, ethanol, 70 ppb MTBE).[65] These factors make ethanol a low health risk in relation to drinking water contamination, even to the most sensitive subgroup, pregnant women.

There is some uncertainty over whether ethanol can affect the migration of benzene and other gasoline constituents when leaked into groundwater. Often, when two liquids are mixed together, their capacity to dissolve and move other materials through soil (co-solvency) can

[60] Carter, W.P.L., "Documentation of the SAPRC 99 Chemical Mechanism for VOC Reactivity Assessment," Draft report to the California Air Resources Board for Contracts No. 92-329 and 95-308, September 13, 1999. (ftp://cert.ucr.edu/pub/carter/pubs/s99doc.pdf)
[61] CARB/CalEPA, (1999).
[62] National Research Council, "Ozone-forming potential of reformulated gasoline," (1999).
[63] NEIWPCC/NESCAUM (2001).
[64] CARB/CalEPA (1999).
[65] NEIWPCC/NESCAUM (2001).

change. The issue of co-solvency of ethanol with gasoline constituents can theoretically extend the distance traveled by benzene, but studies have generally only found this when gasoline contains high concentrations of ethanol. A gasoline blend of 10% ethanol does not appear to substantially affect the behavior of the gasoline plume or individual constituents.[66,67,68] However, this is still an area of active research.

## California Low Emission Vehicle Program

In December of 2005, Connecticut, adopted the LEV II program, which begins with the 2008 model year. Connecticut adopted ruled identical to the California LEV II rules that require automobile manufacturers to provide new cars, light trucks and sport utility vehicles that are lower emitting than vehicles built to meet federal emissions standards. The LEV II Standards provide greater air quality benefits than the existing federal program. Using the Mobile6.2 model, NESCAUM has estimated that implementation of the LEV II standards will result in 10.8% reduction in $NO_X$ and a 4.8% reduction of VOCs by 2020, with a 15.2% reduction in $NO_X$ and a 6.9% reduction in VOCs by 2025.[69] If the model inputs are adjusted to take PZEVs into consideration, the VOC reductions increase to 9.5% by 2020, and to 11.7% by 2025. As has been mentioned previously, EPA has acknowledged recent studies showing that some exhaust emissions may be sensitive to climate-related evaporative fuel parameters in ethanol–blended gasoline.[70] This would apply to both the federal tailpipe emissions program, known as Tier 2, and to LEV II vehicles.

The LEV II program provides more environmental protection than Tier 2. The primary difference between Tier 2 and LEV II standards is that LEV II requires the manufacture and sale of high technology vehicles that comply with a more stringent emissions rate applicable to the entire fleet sold. In addition, LEV II allows the sale of advanced technology vehicles known as PZEVs (e.g., gasoline/electric hybrids that do not need to be “plugged in” or recharged) in lieu of “zero emission” or pure electric vehicles (ZEVs). PZEVs must have no evaporative emissions and “super ultra low” tailpipe emissions. According to EPA’s National Assessment of air toxics, motor vehicles emit 66% of all air toxics; LEV II results in lower toxic air pollutant emissions. It is anticipated that a significant number of new vehicles will eventually be equipped with emission controls that achieve zero evaporative standards ensuring that Connecticut’s fleet of cars and light-duty vehicles includes state of the art emission control technologies.[71]

## 85% Ethanol Fuel and Fuel Economy

### *85% Ethanol Fuel*

---

**66** Redding, B. and Davidson, J. M., Ethanol fate and transport: An updated review of its impact on subsurface gasoline contamination, (2006). (Paper presented at UMass Soils, Sediments and Water Conference).
67 CARB/CalEP (1999)
68 NEIWPCC/NESCAUM (2001).
69 NESCAUM, "Summary of NESCAUM Analysis Evaluating the NOx, HC, and CO Emission Reduction Potential from Adoption of the California Low Emission Vehicle (LEV II) Standards in the Northeast," October 2005.
70 EPA Renewable Fuel Standard (September 2006).
71 DEP, Hearing Report Regarding Proposed Adoption of Section 22a-174-36b of the Regulations of Connecticut State Agencies, which can be found at http://www.dep.state.ct.us/air2/regs/callev.pdf.

85% ethanol fuel blends, commonly known as E-85, are becoming available in many parts of the country. Vehicles with the appropriate modifications to use this fuel, flexible fuel vehicles, are being sold in Connecticut. The RFS set forth in EPAct, which proposes the increasing use of renewable fuels, indirectly supports the use of E-85 since ethanol is the only renewable fuel currently produced in the required quantities. Several of the studies previously cited have included E-85 fuel.

Use of E-85 fuel is restricted in Connecticut due to supplies of ethanol feedstock; this is less of a problem in the Midwest, where ethanol is produced. In the future, if the production of cellulosic ethanol becomes economically viable, the increased supply may allow E-85 to be considered in attainment planning in Connecticut. There are no E-85 dispensing facilities currently available to the public in Connecticut; however, E-85 is available to State fleet vehicles at the Department of Transportation facilities in Newington and Danbury. While the State of Connecticut owns a number of flexible fuel vehicles that are capable of using E-85, the Governor's energy plan calls for meeting the EPAct requirements by investing in more hybrid vehicles for the state fleet.

### *Fuel Economy*

While the use of ethanol promotes renewable fuels, this benefit must be balanced with potential decreases in fuel economy. Because ethanol contains less energy per gallon than gasoline, fuel economy will decrease and greater volumes of fuel will be required. The Wisconsin Department of Natural Resources estimated that in vehicles from the mid 1980's on, using 10% ethanol would have a reduction of approximately 3%, while the improved fuel combustion in older model vehicles may result in no more than a 2% economy loss. However, vehicles using E-85 can have their fuel economy reduced by as much as 30% compared to gasoline.[72] The United States Department of Energy and EPA have compiled information on fuel economy from flexible fuel and gasoline-powered vehicles. The fuel economy of fuel flexible vehicles can be found in the Fuel Economy Guide at the following website: http://www.fueleconomy.gov/. EPA also provides information on the emissions from most of the vehicles currently sold in the United States at http://www.epa.gov/greenvehicles/.

## Preliminary Findings

A major finding from this review and analysis is that the use of ethanol in gasoline does not cause the release of any unique air toxics, but only increases or decreases the levels of contaminants already present in the atmosphere. The change in ambient concentrations is expected to be modest, which is not surprising given that gasoline alone, without oxygenates, is responsible for substantial evaporative and tailpipe emissions. The potential changes in air concentrations due to ethanol and their health implications are summarized in the table below. Our findings relative to the groundwater contamination pathway are also summarized below.

---

[72] The ethanol myth: *Consumer Reports'* E85 tests show that you'll get cleaner emissions but poorer fuel economy ... if you can find it, Consumer Reports, October 2006. Consumer Reports "The Ethanol Myth"

**Table 3: Summary of Ethanol in Gasoline Effects on the Environment and Health Risks**

| Factor | Chemical | Potential Air and Water Quality Impacts | Potential Impact on Human Health |
|---|---|---|---|
| Evaporative Emissions | Ethanol | 73% (+3.7 ppb) ↑ | Insignificant |
| | Total VOCs | Current studies are insufficient to assess the change in VOC relative to MTBE base gas and the resulting impacts in CT | Current studies are insufficient to assess change in VOC ozone precursors relative to MTBE base gas in CT |
| | Benzene | Small ↑ (<10%) relative to base gas but no change relative to MTBE-based fuel | No change in benzene cancer risk from MTBE-based fuel |
| Tailpipe Emissions | Acetaldehyde | Possible ↑ but uncertain | Likely to be Insignificant |
| | Formaldehyde | Slight ↓ relative to MTBE-based fuel | Insignificant |
| | PAN | Slight ↑relative to MTBE gas | Insignificant |
| | $NO_X$ | Up to 12% ↑ possible relative to base gas, possible ↑ relative to MTBE | Insignificant |
| | 1,3-Butadiene | No change | Insignificant |
| | GHG | Reductions ↓ through emissions and displacement | Significant as a benefit to limit climate change |
| Ozone | ---- | Because ozone production relies on meteorology plus $NO_X$ and VOC, impacts cannot be predicted | Unknown |
| Groundwater Contamination | Ethanol | Faster breakdown & higher drinking water target than MTBE | Unlikely to be a drinking water health risk |
| | Other gasoline constituents | May travel farther if high ethanol concentration but less likely at 10% ethanol | Insignificant at 10% ethanol |

- No published reports to date have changed the conclusion reached in the NESCAUM 1998 report[73] that the addition of MTBE to gasoline displaces components that pose a greater cancer risk. Since ethanol is less of a cancer concern than MTBE, this is even more the case for ethanol-blended fuels.

- Connecticut's implementation of the California LEV II Program,[74] beginning with the 2008 model year, will initiate a changeover in Connecticut's vehicle fleet that significantly decreases air pollution.
    - Exhaust emissions are greatly reduced in low emission vehicles (LEVs).[75,76]

[73] Ibid.
[74] R.C.S.A. Sec. 22a-174-36b.
[75] CRC Project No. E-67, January 30, 2006. (See summary presentation at: http://www.aqmd.gov/tao/ConferencesWorkshops/06_EthanolWS/04-TomDurbin_revised_background.pdf.) .
[76] EPA Renewable Fuel Standard (September 2006).

    - New vehicles will eventually be equipped with emission controls, such as those required for partial zero emission vehicle (PZEV)[77] systems, that achieve zero evaporative standards for VOCs.

- Evaporative emissions from ethanol-blended fuel may be influenced by the effect of permeation through the vehicle fuel system. Permeation emissions were shown in recent studies to increase with 6 %ethanol blends (E-6) and E-10 compared to non-oxygenated fuel, especially at higher temperatures. The extent of increase varies substantially with vehicle design. The resulting impact on emissions inventories depends on the fraction of total evaporative emissions attributable to permeation, and cannot be quantified based on available data.

- The use of ethanol in gasoline does not cause the release of any new air toxics, but only increases or decreases the levels of contaminants already present in the atmosphere. The change in ambient concentrations is expected to be modest in that gasoline alone, without oxygenates, is already responsible for substantial evaporative and tailpipe emissions.

- Combustion of E-10 is expected to increase $NO_X$ emissions, as compared to both RFG without oxygenate and MTBE blends. Ozone production on high ozone days in Connecticut can be more dependent upon $NO_X$ than on VOC concentrations.

- Specific changes in atmospheric levels of air pollutants resulting from the changeover to ethanol-blended fuels cannot be quantified because the available data, mostly from studies in California, cannot be reliably extrapolated to Connecticut.

- Continued evaluation of VOC reduction strategies for off-road gasoline engines[78] will be necessary. Off-road sources constitute a significant portion of Connecticut's VOC emissions and there are federal limits on states' ability to regulate them.

- Passage of EPAct, which repealed the federal CAA oxygenate requirement nationwide, has eliminated the need for Connecticut to consider requesting a waiver from the oxygenate requirement in RFG.

- EPAct restricts states from adopting new "boutique fuels" programs. Any state requirement that expands, limits or prohibits the use of ethanol in RFG could constitute the creation of a new boutique fuel. Under EPAct there are hurdles that will be difficult to overcome; these must be considered in planning future strategies.

- Continued evaluation of emerging data is necessary to assess any changes in environmental quality potentially attributable to the use of ethanol as an additive in gasoline and should be considered during attainment planning. Studies currently

[77] To qualify for PZEV credit, a vehicle must be certified to the super ultra low emission level exhaust standards, have zero evaporative emissions and have a 150,000-mile warranty for the performance of the emission control equipment. CARB, Staff Report: 2000 Zero Emission Vehicle Program, Biennial Review, August 7, 2000, page 5.
[78] Off-road gasoline engines include, but are not limited to, lawn mowers and other garden equipment, snow blowers and off-road recreational vehicles such as snowmobiles.

underway may begin to resolve these issues. Connecticut should not consider a new research program until these studies have been published and evaluated.

- The continued use of ethanol-blended fuels has a number of benefits for Connecticut:
    - Ethanol is integral to reducing the state's dependence on fossil fuels; and
    - Ethanol reduces greenhouse gas emissions necessary to meet the goals of the Climate Change Action Plan by displacing 165 million gallons of gasoline.

# Appendices

## **Appendix 1** *(See Section 6)*

***Substitute Senate Bill No. 313***

## ***Public Act No. 06-53***

### ***AN ACT CONCERNING PROTECTION OF PUBLIC WATER SUPPLY SOURCES.***

Be it enacted by the Senate and House of Representatives in General Assembly convened:

Section 1. Section 8-3i of the general statutes is repealed and the following is substituted in lieu thereof (*Effective October 1, 2006*):

(a) As used in this section "water company" means a water company, as defined in section 25-32a, and "petition" includes a petition or proposal to change the regulations, boundaries or classifications of zoning districts.

(b) When an application, petition, request or plan is filed with the zoning commission, planning and zoning commission or zoning board of appeals of any municipality concerning any project on any site **[**which**]** that is within the aquifer protection area delineated pursuant to section 22a-354c or the watershed of a water company, the applicant or the person making the filing shall provide written notice of the application, petition, request or plan to the water company and the Commissioner of Public Health in a format prescribed by said commissioner, provided such water company or said commissioner has filed a map showing the boundaries of the watershed on the land records of the municipality in which the application, petition, request or plan is made and with the planning commission, zoning commission, planning and zoning commission or zoning board of appeals of such municipality or the aquifer protection area has been delineated in accordance with section 22a-354c, as the case may be. Such notice shall be made by certified mail, return receipt requested, and shall be mailed **[**within**]** not later than seven days **[**of**]** after the date of the application. Such water company and the Commissioner of Public Health may, through a representative, appear and be heard at any hearing on any such application, petition, request or plan.

(c) Notwithstanding the provisions of subsection (b) of this section, when an agent of the zoning commission, planning and zoning commission or zoning board of appeals is authorized to approve an application, petition, request or plan concerning any site [which] that is within the aquifer protection area delineated pursuant to section 22a-354c or the watershed of a water company without the approval of the zoning commission, planning and zoning commission or zoning board of appeals, and such agent determines that the proposed activity will not adversely affect the public water supply, the applicant or person making the filing shall not be required to notify the water company or the Commissioner of Public Health.

Sec. 2. Section 22a-42f of the general statutes is repealed and the following is substituted in lieu thereof (*Effective October 1, 2006*):

When an application is filed to conduct or cause to be conducted a regulated activity upon an inland wetland or watercourse, any portion of which is within the watershed of a water company as defined in section 25-32a, the applicant shall provide written notice of the application to the water company and the Commissioner of Public Health in a format prescribed by said commissioner, provided such water company or said commissioner has filed a map showing the boundaries of the watershed on the land records of the municipality in which the application is made and with the inland wetlands agency of such municipality. Such notice shall be made by certified mail, return receipt requested, and shall be mailed [within] not later than seven days [of] after the date of the application. The water company and the Commissioner of Public Health, through a representative, may appear and be heard at any hearing on the application.

Sec. 3. Section 25-32 of the general statutes is amended by adding subsection (o) as follows (*Effective October 1, 2006*):

(NEW) (o) The commissioner may adopt regulations, in accordance with the provisions of chapter 54, that incorporate by reference the provisions of the federal National Primary Drinking Water Regulations in 40 C. F. R. Parts 141 and 142, promulgated by the United States Environmental Protection Agency, provided such regulations (1) are consistent with other regulations adopted pursuant to this section, and (2) explicitly incorporate any future amendments to said federal regulations.

Sec. 4. Subdivision (4) of section 7-244h of the 2006 supplement to the general statutes is repealed and the following is substituted in lieu thereof (*Effective from passage*):

(4) Sell, lease, grant options to purchase or to renew a lease for any interest in all or any portion of property of such authority, real or personal, tangible or intangible, determined by such authority to be no longer used by or useful to such authority, on such terms as such authority may determine to be necessary, desirable or convenient, subject to the provisions of applicable law concerning such sale, lease or options, except

that such authority may not sell, lease or otherwise convey any interest in land classified under [subsection (c) of section 25-37] section 25-37c as class I or class II water-company-owned land unless specifically authorized in subdivision (5) or (17) of this section.

Sec. 5. Section 7-244q of the 2006 supplement to the general statutes is repealed and the following is substituted in lieu thereof (*Effective from passage*):

Without limiting the generality of any and all rights, privileges and powers granted to an authority under the provisions of sections 7-244g to 7-244s, inclusive, and subject to the provision of said sections 7-244g to 7-244s, inclusive, an authority shall have the same rights, privileges and powers related to the issuance of bonds as are granted to a municipality or town, as such terms are defined in chapter 109. Where said chapter 109 authorizes or requests action by a municipal or town official, officer or body, the board of directors of an authority shall designate an official, officer or body of such authority to take such action on behalf of such authority, except that the provisions of sections 7-373 to 7-374a, inclusive, [7-347c] 7-374c, 7-378b, 7-378d and 7-378f do not apply to such authority. For purposes of this section, references in said chapter 109 to "taxes" or "taxation" mean charges or assessments by an authority.

Sec. 6. (*Effective from passage*) (a) The Commissioners of Environmental Protection and Public Health shall study the costs and benefits of using ethanol as a gasoline additive in this state as a means of meeting the requirements of the federal Clean Air Act. Such study shall examine (1) the public health implications of exposure to unsafe levels of ethanol and other toxics unique to ethanol-blended gasoline, (2) how using ethanol as a gasoline additive effects motor vehicle emissions and impacts on the state's implementation plan under the federal Clean Air Act, and (3) health risks associated with chronic exposure to ethanol or ethanol-blended gasoline.

(b) Not later than December 31, 2006, the Commissioner of Environmental Protection shall, within available appropriations and in accordance with section 11-4a of the general statutes, report the findings of the study authorized in subsection (a) of this section to the joint standing committees of the General Assembly having cognizance of matters relating to public health and the environment. In addition to such findings, such report shall include (1) an analysis of any reports or recommendations made by the Northeast States for Coordinated Air Use Management and the New England Interstate Water Pollution Control Commission, (2) an analysis of whether Connecticut should continue to use ethanol as a gasoline additive and, if not, an analysis of the process for seeking a waiver from the United States Environmental Protection Agency in order to discontinue the use of ethanol as a gasoline additive in this state, (3) an analysis of the effect of ethanol on the state's air quality, (4) an update on the status of any action taken by other states regarding the use of ethanol as a gasoline additive, (5) recommendations for new ethanol exposure standards for gasoline-related occupations and for sensitive population subgroups, and (6) specific recommendations on alternative or supplemental air pollution reduction programs such as alternative motor vehicle fuel incentives, mass transit and employee commuter programs.

Approved May 8, 2006

# Appendix 2

## Literature Review of Studies Evaluating the Air Quality and Water Quality Impacts of Ethanol in Gasoline

**Prepared by NESCAUM**
**October, 2006**

**Jacobson, Mark Z., Effects of Ethanol (E85) Versus Gasoline Vehicles on Cancer and Mortality in the United States, Department of Civil and Environmental Engineering, Stanford University, August 30, 2006.**

- Increased use of E85 as a motor vehicle fuel may increase ozone-related mortality, hospitalizations, asthma incidence, and PAN-related eye irritation.
- It is estimated that by 2020, acetaldehyde emissions from an E85-fueled vehicle will be approximately 20 times those of a gasoline-fueled vehicle.
- Aldehydes in the ambient air increase the concentration of hydroxyl radicals which in turn hasten the transformation of sulfur dioxide (gaseous) to sulfate (particulate).

**Harold Haskew and Dennis McClement, Fuel Permeation from Automotive Systems: E0, E6, E10, and E85, Interim Report, CRC Project E-65-3, August 2006**

- As a follow-up to the original E-65 permeation study, the authors compared permeation emissions from fuels with varying ethanol content, for vehicles with “near-zero” (LEV II) and “zero” (P-ZEV) evaporative emissions fuel systems.
- Final report is due Fall 2006.
- The 2 most recent test rigs (’00 &’01 vehicles) from the first study were tested along with one test rig each from a LEV-II, PZEV, and flex-fuel vehicle.
- Four fuel blends were originally tested: E0, E6, E6Hi (increased aromatics content), and E85. E20 was added mid-way through; results have not yet been presented.
- Preliminary results are presented, but have not been statistically analyzed and thus should not be assumed to be meaningful:
    - Permeation emissions increased with E6, E6Hi, and E10 for all vehicles.
    - LEV-II and PZEV systems had much lower emissions than the 2000 and 2001 vehicles. The PZEV fuel system showed the smallest increase in permeation emissions with ethanol blends.
    - E85 in the flex-fuel vehicle had *lower* permeation than E0.
    - No difference in permeation rates was measured between E6 and E10 blends.
    - Permeation rates were lower with the E6Hi compared to E6.
    - Average specific reactivities of permeates from ethanol blends were lower than from E0.

**CARB, <u>Offroad Modeling Change Technical Memo DRAFT,</u> June 2006**

- Preliminary test results are presented in a draft memo with the disclaimer "Do not cite or quote"
- CARB Staff measured permeation emissions from 5 late-model walk-behind lawnmowers with MTBE and E6 blended gasoline; 14 gas cans were also tested.
- Test results will likely be used to modify OFFROAD model.
- Permeation emissions were found to increase from the ethanol blend by 20-30%.
- The effect of ethanol on emissions was found to increase with ambient temperature.
- Permeation emissions from gas cans were found to increase by an average of 54%.

**CARB, <u>Predictive Model Back-up/EMFAC Model Change DRAFT</u>, June 2006**
**CARB, <u>On- and Off-Road Ethanol Emission Impacts,</u> Presentation, June 2006**
**AIR, Inc (for WSPA), <u>Comments on ARB Ethanol Permeation Inventory Estimates</u>, Presentation, July 2006**
**CARB, <u>Permeation Issues Slides</u>, Presentation, August 2006**
**AIR, Inc, <u>Continuing Permeation Issues</u>, Presentation, August 2006**

- ARB Staff proposes to change EMFAC fuel-correction factors based on extrapolations of findings from the CRC E-65 study.
  - Adjustment factors would be assigned for each EMFAC evaporative category - "Normal", "Moderate", and "Liquid Leaker", to account for the ratio of E6-to-MTBE permeation emissions. Since no "leakers" were tested, ARB assumed a ratio of 1.05:1 for this category.
  - Since E-65 data covered only the permeation emissions (not venting and leaking), ARB developed a "Permeation Fraction" to extrapolate permeation emissions data to all evaporative modes.
  - EMFAC results based on ARB's methodology:
    - For 2005 vehicles, the use of E6 instead of MTBE would increase evaporative emissions by 9% and total ROG by 4%.
    - For 2015, the increases would be 6.5% for total evaporative and 3.8% for total ROG.
- WSPA and AIR, Inc dispute several aspects of ARB methodology.
  - They claim that ARB's Permeation Fraction methodology is flawed and overstates the impact of ethanol on total evaporative emissions.
  - They claim that if ARB were to incorporate the results of the ongoing E65-3 testing (described above, including low-evap fuel systems), the ethanol impacts on permeation and ozone-forming potential (OFP) would be reduced even further.
  - They claim that the difference in methodologies results in an overall difference in OFP of 1.4%, with a cost effect comparable to lowering RVP by 0.2-0.3.

**Worldwatch Institute, <u>Biofuels: Renewable Energy or Environmental Disaster in the Making?</u>, June 2006.**

- Biofuel production will always be less energy and carbon efficient, compared to burning biomass for primary energy and heat generation, because of the inherent energy-intensive refining process.

- On a life-cycle basis, ethanol as a fuel produces 13% less greenhouse gas emissions, compared to gasoline but only if the co-products from producing ethanol displace production of other animal feeds.
- Nitrogen fertilizers, used in production of crops including biofuel crops, increase $N_2O$ emissions from soils. $N_2O$ is 310 times more potent as a greenhouse than $CO_2$ and remains in the atmosphere considerably longer.
- Nitrogen fertilizers also increase nutrient overload, leading to eutrophication of bodies of water.
- Market forces have a strong potential to shift biofuel crop production to the tropics. Consuming nations have no control over the farming practices used to produce these crops. Conceivably, more rain forest lands and mangrove swamp lands will be converted to biofuel crop production, causing a loss of these natural carbon sinks and other negative environmental impacts. As an example, sugarcane production typically is not done in an environmentally friendly manner and it has negative impacts on biodiversity.
- Consuming countries could take greenhouse gas reduction credits by using these tropically-produced biofuels, and yet the producing countries would incur greenhouse gas debits through their agricultural practices to produce the biofuel crops. In effect, the consuming countries would be "outsourcing" their carbon emissions to producing countries.
- Biofuel crop production must either reduce acreage devoted to food crop production or force more natural lands into agricultural production.
- Only biofuels produced through sustainable practices should be classified as truly renewable.

**Thomas Durbin et al (UCR/CE-CERT), Effects of Ethanol and Volatility on Exhaust Emissions: Final Report, CRC Project # E-67, February 2006.**
**Mike Ingham (Chevron), Summary of CRC E-67 Effects of Ethanol & Volatility Parameters on Exhaust Emissions, Presentation to CARB Predictive Model Workgroup Meeting, February 2006.**

- Tests were conducted by UC Riverside on 12 vehicles (MY 2001 thru 2003, ranging from LEV to SULEV) to compare exhaust emissions from 12 fuels of varying ethanol content (0%, 5.7%, 10%) and volatility parameters.
- Ethanol content and mid-fill and back-end volatility have complex interactive effects on exhaust emissions.
- NMHC and NOx each were found to increase with increasing ethanol content for certain blends but not for others.
- Increases were measured for NMOG (14%), acetaldehyde (73%), benzene (18%), and 1,3-butadiene (22%) when ethanol content was increased from zero to 10%.
- For some blends CO emissions decreased with increasing ethanol content.

**European Environment Agency, How Much Bioenergy Can Europe Produce Without Harming the Environment?, 2006.**

- Increased bioenergy production (e.g., ethanol, biodiesel) has the potential to adversely impact and/or alter the environment in Europe. Principal among the potential negative consequences are:
    - Increase in intensive agricultural practices.

    - Loss of biodiversity, depending on the choice of crops or other biomass.
    - Increased competition for sources of water.
    - Release of soil carbon through increased tilling.
    - Increased use of pesticides and fertilizers.
    - Soil compaction and leaching.
    - Increased wildfire potential, depending on the choice of crops or other biomass.
    - Reduced production of crops grown for food and fodder.
- If waste materials are utilized more extensively for biofuel production, less farm and forest land will have to be devoted to producing the necessary biomass.
- Raising of perennials (e.g., grasses) for production of biomass generally is a more environmentally friendly approach, as compared to production of corn, rape seed, etc.

**California Environmental Protection Agency, Office of Environmental Health Hazard Assessment, Atmospheric Chemistry of Gasoline-Related Emissions: Formation of Pollutants of Potential Concern (Draft), September 2005.**

- Uncombusted ethanol reacts with hydroxyl radicals in the atmosphere to form acetaldehyde and smaller amounts of formaldehyde and glycolaldehyde.
- Acetaldehyde is also a byproduct of ethanol combustion.
- Acetaldehyde emissions from light-duty vehicles are higher when the gasoline has been oxygenated with ethanol when compared to gasoline oxygenated with MTBE.

**Australian Government Biofuels Taskforce, Report of the Biofuels Taskforce to the Prime Minister, August 2005.**

- This report assumed E10 fuel achieves a 40% reduction in particulate emissions compared to use of gasoline without ethanol, but at the same time called for further study to better characterize the particulate emission reduction potential.
- Extensive incorporation of biofuels (e.g., ethanol, biodiesel) into the Australian fuel supply is assumed to achieve a 2-5% reduction in greenhouse gas emissions. At the same time, the report pointed out that if greenhouse gas reductions were the only reason for use of biofuels, there are other more cost-effective strategies available to achieve similar reductions.
- E10 may not be a suitable fuel for use in 2-stroke engines, due to its phase-separation tendency.
- E10 is not an optimal fuel for vehicles with carburetors or mechanical fuel injection, typically pre-1986 vehicles.
- E10 may worsen the atmospheric formation of secondary organic aerosols. More research is needed.
- Under the Kyoto Treaty, countries may only take credit for greenhouse gas reductions resulting from displacement of conventional fuels, if there is a reduction in consumption of domestically refined conventional fuel (i.e., reduction in import of conventional fuel is not creditable).
- There is a net increase in “lifecycle” PM emissions as a result of producing ethanol for fuel purposes. The increase is primarily due to the energy requirements to operate mills and distilleries. However, if the energy from cogeneration is fully utilized, then lifecycle PM emissions are less, compared to use of conventional fuels.

- Ethanol blends require more energy to produce, compared to conventional petroleum fuels and thereby result in a net increase in greenhouse gas emissions. However, the reduction in greenhouse gas emissions from the combustion of E10, compared to conventional petroleum fuels, more than offsets this "upstream" increase.

**Novoenzymes & BBI International, Fuel Ethanol: A Technological Innovation, June 2005**

- According to the U.S. Department of Agriculture, based on 1995-97 corn crop yield data, there is a 34% net energy gain in producing and using ethanol as fuel.
- Based on 2002 crop yields, the net energy gain is 53%.
- The grain dryer accounts for 60% of the emissions from corn ethanol production. Use of regenerative thermal oxidizers in the drying process will significantly reduce emissions.
- Anaerobic digesters, used to treat waste water from corn ethanol production, generate methane that can be used as a supplemental fuel in the process.

**Harold Haskew and Dennis McClement, Fuel Permeation from Automotive Systems: Final Report, CRC Project #E-65, September, 2004**

- Tests were conducted on 10 vehicles (MY 1978 thru 2001). Complete fuel systems were removed from the vehicles and installed on test rigs; evaporative emission rates were measured for steady-state and diurnal conditions.

Typical Test Rig for CRC E-65 Permeation Study.

- Three fuels were compared: MTBE blend, E-6, and non-oxygenated gasoline.
- Average permeation emissions from the ethanol blend were 65% higher than from MTBE and 45% higher than from the non-oxygenated fuel.
- No statistical difference was measured between the MTBE and non-oxygenated fuels.
- Non-ethanol permeation rates generally increased with the ethanol blend. The researchers expressed surprise at this observation and could not explain its cause.
- Permeation rates were lower (from all fuels) for vehicles with "enhanced" evaporative emissions (post-1996).
- Early-90's non-metallic tanks showed higher emissions than other systems for all fuels tested.

**International Energy Agency, Biofuels for Transport: An International Perspective, April 2004.**

- There is a mismatch between countries where biofuels can be produced at lowest cost (e.g., tropical and subtropical areas such as Brazil and India, where sugarcane is grown for ethanol production) and countries where demand for biofuels is growing most rapidly (e.g., the U.S., the E.U. countries).

- In order to displace 5% of gasoline consumption in the U.S. with ethanol and do so through domestic sources, 8% of U.S. cropland would have to be converted from food production to energy production. A 10% displacement would require a 14% conversion. Such displacement will impact food supply and therefore the price of food.
- Globally, in order to displace 10% of world gasoline consumption with ethanol, a substantial international marketing network would have to be established. Government policies on biofuels will need to be more closely reconciled with policies on energy, environment, trade, and economics.
- Presently, fossil fuels are the primary energy source for powering boilers and fermentation systems for production of ethanol. This negatively impacts the carbon benefits of biofuels.
- Determining the actual greenhouse gas reduction benefits from use of biofuels depends on a number of variables, including:
    - The amount of fossil fuel required to grow the crops, transporting the crops to the distiller, producing the ethanol, and delivering it to fueling stations.
    - The feedstock-to-ethanol conversion efficiency.
    - Co-product credits (animal feed, cogeneration).
    - Vehicle fuel economy assumptions.
    - Feedstock (e.g., corn, wheat, sugarcane, cellulose).
    - Which greenhouse gases are considered (e.g., $CO_2$, $N_2O$, $CH_4$).
    - Nitrogen storage and release patterns by plants and soil.
    - Land use changes (e.g., forest to agriculture, prairie grass to agriculture) and associated loss of sequestered carbon.
- Use of sugarcane as a feedstock presently is the most economical means to produce ethanol and may remain so. This is primarily because the ethanol yields per acre are very high, due to intense tropical sunlight, high soil productivity and low fertilizer demands. The energy for the distillation process can be derived from the sugarcane plant residue (bagasse). Modern distillation plants are co-generation facilities, producing electricity from burning the bagasse. Thus, the overall environmental impact from a substantial increase in use of ethanol as fuel depends to a large extent on the practices associated with growing sugarcane.
- Production of ethanol from cellulose (despite its carbon-reducing benefits) may not be able to compete economically with ethanol production from sugarcane.
- In Brazil, producers have the flexibility to devote their sugarcane crop to ethanol production, refined sugar production, or a combination of the two, depending on market forces. Thus, as major exporters of refined sugar to world markets, decisions by Brazilian producers substantially affect the cost of sugar worldwide. Similarly, if there is a substantial increase in worldwide demand for ethanol, Brazilian producers have the potential to substantially affect the cost of ethanol. Market forces, as described, may have indirect effects on the environment.

**CONEG, <u>Removing MTBE from Gasoline: Implications for the Northeast Gasoline Supply, Volume I</u>, Report of the Northeast MTBE Roundtable, April 2004.**

- CONEG conducted study, lit review, and interviews with industry to evaluate impact on supply in region due to phase-out of MTBE in NY and CT.

- Winter fuel switch had minor impacts on refining (slight change to RFG blend), pipelines (alter distribution schemes), terminals (to accommodate blending and stocking of multiple fuels), and dealers.
- Petroleum and ethanol industries successfully managed switchover in time for Jan 1 2004 deadline.
- Summer RFG is more switch required more substantive alteration in production; summer fuel will thus be more vulnerable than winter fuel to supply disruptions and price spikes.
- Different MTBE rules in neighboring states are not expected to initially affect supply unless major price differential develops between MTBE and ethanol fuels. Over time, distribution system may evolve reflecting the relative size of the NY and CT markets in the region.
- Cost differential in production is minor compared to other global market factors; however the addition of a "complicating factor" in the supply chain increases vulnerability to market "hiccups".
- States can help industry to smooth the transition (as CT and NY did) by ensuring adequate lead time in regulations, monitoring inventory levels to ensure early detection of supply problems, and outreach to independent retailers.

**Hosein Shapouri et al (USDA & DOE), <u>The 2001 Net Energy Balance of Corn-Ethanol</u>, 2004**

- The USDA estimated the net energy balance for corn ethanol based on 2001 data crop-yield data for the nine largest ethanol-producing states, in an attempt to improve on previous estimates published in 1995, 2002, and 2003, and specifically in response to Pimentel and others who had claimed USDA had understated the energy intensity of process inputs (e.g. fertilizers, irrigation).
- Corn yield, a critical component of net energy estimation, may vary widely from year to year. USDA used a 3-year average yield from the nine largest corn-producing states.
- 50,000 Btu was required to produce one bushel of corn in 2001.
- USDA used data provided by industry for energy used for seed and nitrogen; GREET data for production and transport of pesticides and herbicides and for transport of corn; survey data for plant efficiencies, and ASPEN model data to allocate energy to byproducts.
- Resulting energy ratios (energy out divided by energy in) were 1.57 for wet milling, 1.77 for dry milling, overall average of 1.67.

**Tardif, Robert, Liu, Ling, and Raizenne, Mark, <u>Exhaled Ethanol and Acetaldehyde in Human Subjects Exposed to Low Levels of Ethanol</u>, Inhalation Toxicology, 16:203–207, 2004.**

- Inhalation of ethanol at low concentrations resulted in measurable levels of acetaldehyde in alveolar air.

**Pimentel, David, <u>Ethanol Fuels: Energy Balance, Economics and Environmental Impacts are Negative</u>, Natural Resources Research, Vol. 12, No. 2, June 2003.**

- 29% more energy is required to produce a gallon of ethanol, compared to the energy content of the same gallon. This does not include the energy required to transport the fuel.

- About 12 gallons of waste water must be removed and sewered to produce one gallon of ethanol. Water is removed through a distillation process, requiring considerable expenditure of energy.
- 70% of corn grain produced in the U.S. presently is fed to livestock. Diverting significant volume of corn to ethanol production will drive up the price of animal feed and in turn increase the cost of meat to the consumer.
- Corn production requires use of more herbicide, insecticide and nitrogen fertilizer than any other crop produced in the U.S.
- U.S. export of corn and other grains is one of the most significant mitigating factors in the U.S. balance of payments deficit. These grains also help to feed a substantial portion of the world population. Diversion of corn to domestic ethanol production will negatively impact the balance of payments and the world food supply.

**Energy Future Coalition, Challenge and Opportunity: Charting a New Energy Future, June 2003**

- The ability to convert cellulosic biomass is key to future successful utilization of ethanol and other energy products. Waste products such as wheat and rice straw would become a commodity. Utilization of waste products in this manner will reduce or minimize the diversion of food crops into energy production.
- The "relevant issues" surrounding the production of biofuel crops are protection of wildlife and biodiversity, soil quality and erosion, air and water quality, forest health, and use of genetically modified organisms.

**David L. Greene (ORNL) and Andreas Schafer (MIT), Reducing Greenhouse Gases from US Transportation, Pew Center on Global Climate Change, May 2003.**

- Renewable/Petroleum blended fuels can reduce GHGs from transportation by 2% in 2015 and 7% in 2030
  - Cellulosic ethanol is commercialized, and
  - Current tax subsidies are continued.
- Biofuels' role in transportation is limited by availability of land resource and economic reliance on co-products.
- Combined effect of higher engine efficiencies (due to increase in octane rating from ethanol fuel) and low carbon content could result in 100% reduction in CO2 emissions.

**NEIWPCC and NESCAUM, Health, Environmental, and economic Impacts of Adding Ethanol to Gasoline in the Northeast States, July 2001:** See summary in text of main report.

- New England Governors' Conference Committee on the environment commissioned NEIWPCC and NESCAUM to report on air, water, infrastructure and economic impacts of converting gasoline supply from MTBE to ethanol blends. This report contains a literature review and general recommendations. Detailed technical analysis should be conducted for fate and transport, region-specific economic impacts.

- Key findings – Health:
  - Ethanol appears to be one of the least toxic of the major components of gasoline.

- Preliminary analyses indicate that direct exposure to ethanol in air and water supplies is not expected to pose public health risks.
    - Potential for other adverse impacts (e.g. developmental, long-term) from large-scale exposure to low levels of ethanol is uncertain.
- More study needed to estimate of effects of increased ethanol use on exposure to toxic constituents such as PAN and acetaldehyde.
- Air toxic and ozone precursor emissions could increase if ethanol replaces MTBE; however, these impacts can be minimized with appropriate policy measures.
- Air quality benefits may diminish from replacement of MTBE with ethanol, but will still be significant compared to conventional gasoline.
- CO benefits from ethanol will partially offset adverse ozone impacts.
- Low-level ethanol contamination of groundwater (less than 400 μg/L) is not expected to substantially alter blood alcohol concentrations or produce as significant health risk.
    - Higher concentrations may begin to increase health risks but are not expected to materially add to endogenous ethanol concentrations until there is daily exposure to at least 10mg/L (ppm). Such concentrations are unlikely given the physical and chemical properties of ethanol.
- The hazard potential for ethanol is greater than that for MTBE in terms of the types of irreversible damage possible from repeated high-level exposures.

- Key findings – Environmental:
  - Because it degrades quickly, ethanol poses significantly less risk to water resources than MTBE. However, the following environmental transport properties of ethanol are cause for concern:
    - At high concentrations, ethanol can make other gasoline constituents more soluble in groundwater.
    - When present in a gasoline spill, ethanol can delay the degradation of other, more toxic components in gasoline.
    - Ethanol can cause greater lateral spread of the layer of gasoline on top of the water table.
  - While ethanol is likely to have fewer adverse impacts than MTBE in small-volume gasoline spill scenarios, the relative impacts of large-volume gasoline spills are harder to generalize.
  - Under acute exposure conditions, ethanol is 3.7 times less toxic to aquatic life than MTBE. .
  - The breakdown of ethanol in surface waters could potentially result in the consumption of significant quantities of dissolved oxygen in the surface water body. Depending on conditions in the surface water body and the amount of ethanol introduced, this could result in fish kills.
  - Much of the technology developed to clean up gasoline and MTBE in soil should also work for neat ethanol and blends. Testing is needed to determine the cost and relative efficacy of the various cleanup options.
  - Due to its high solubility, treatment technologies that rely on the physical separation of ethanol from water (e.g. adsorptive filters) will not be effective.

    - Biological treatment technologies offer significant promise, though in-situ bioremediation technologies would have to be scaled-up relative to those currently used.

- Key findings: Ethanol Infrastructure:
    - Due to ethanol's affinity for water, ethanol-containing gasoline cannot be transported through existing pipelines.
    - Ethanol will need to be transported and stored separately from gasoline until the point where it is loaded into tanker trucks for delivery to retail stations.
    - Segregated ethanol storage tanks and new blending equipment will be needed at distribution terminals.
    - Designing and building this infrastructure could cost the Northeast $30 million and take two or more years.
    - Space constraints may be an important obstacle in siting new tanks at existing storage and distribution facilities.
    - Regional barge, rail and truck facilities would need to be added or expanded at bulk terminals and ports to accommodate the amount of ethanol needed to meet RFG demand.
    - The materials used to fabricate UST/AST systems have evolved over time to accommodate the storage of ethanol and ethanol blends. However, some existing single-walled fiberglass reinforced plastic tanks fabricated prior to January 1, 1984, as well as some gaskets, sealants, adhesives and other component materials, may not be compatible with ethanol. The degradation of non-compatible materials may lead to new releases.
    - Ethanol will enhance the suspension of water and loosen rust and deposits from the interior walls of storage systems. Water and scoured deposits could cause or contribute to premature failure of some leak monitoring systems and dispensing hardware.

- Key recommendations:
    - Northeast states should develop coordinated, consistent analytical methods and implement monitoring of ethanol impacts on air and water quality.
    - Regionally coordinated phase-out of MTBE; Congress should remove oxygen requirement for RFG; pending congressional action, USEPA should grant state requests for oxygenate waivers.
        - States should develop a model waiver request and technical support document.
    - Any federal ethanol requirement should be based on national average sales quotas, and should incentivize cellulosic production.
    - USEPA should
        - Establish air toxics standards based on actual reductions achieved by RFG (to prevent "backsliding").
        - Repeal the 1-lb RVP waiver for ethanol-blended gasoline.
    - Region's gasoline storage and transport system should be evaluated and upgraded where necessary to accommodate ethanol blends.
    - Air shed and human exposure modeling should be conducted.

- Opportunities should be explored to develop indigenous industry for cellulosic production in Northeast.

**California Environmental Protection Agency, Office of Environmental Health Hazard Assessment, Potential Health Risks of Ethanol in Gasoline, December 1999.**

- Ethanol readily undergoes microbial degradation in the environment. In contrast, MTBE is not readily degraded.

**Ulrich, Glenn (For Governors' Ethanol Coalition), The Fate and Transport of Ethanol-Blended Gasoline in the Environment, October 1999.**

- Ethanol, being highly soluble in water, will readily contaminate any ground or surface water to which it comes into contact.
- Ethanol does not migrate significantly in groundwater because it rapidly undergoes biodegradation. However, one of its degradation products, acetic acid, has a lower rate of biodegradation and therefore tends to accumulate in groundwater. There is some evidence that degradation of benzene, toluene, ethylbenzene, and xylene (BTEX) in the environment is inhibited by the presence of acetic acid.
- Ethanol in gasoline when compared to gasoline without ethanol, tends to decrease carbon monoxide, VOC and benzene emissions but increase nitrous oxide, acetaldehyde, and PAN emissions.
- Highly concentrated ethanol (as in E85) when coming into contact with water, acts as a co-solvent which increases the solvency of BTEX in water. However, at an E10 formulation, there is not enough ethanol present in contaminated water to have this co-solvency effect.
- Ethanol is a naturally occurring intermediate compound produced in natural fermentation processes. Therefore, there are plenty of natural bacteria strains in the environment which readily act on ethanol to break it down.
- According to a study in Brazil conducted on sediment slurries, high concentrations of ethanol may inhibit the aerobic degradation of BTEX because of the preferential utilization of ethanol by aerobic bacteria and because of the depletion of oxygen as ethanol is broken down. However, since anoxic conditions tend to prevail in aquifers, this phenomenon may not be important in groundwater pollution remediation.

**California Air Resources Board, Literature Review: Evaluation of the Potential Air Quality Impacts of Substituting Ethanol-blended Gasoline for MTBE-blended Gasoline, September 24, 1999.**

- According to a study in Denver, Colorado, when wintertime gasoline was converted from a predominant MTBE blend to an ethanol blend, there were no significant differences found in ambient levels of acetaldehyde versus formaldehyde. However, photochemical production and destruction of carbonyls tends to predominate and thereby suppresses the direct emissions effect.
- In Brazil, where gasohol (22% ethanol) and "neat" ethanol are the predominant light-duty motor vehicle fuels, ambient acetaldehyde concentrations in urban areas are considerably higher than anywhere else in the world.

- Ethanol breaks down in the atmosphere into acetaldehyde which in turn breaks down into peroxyacetyl nitrate (PAN).

**Argonne National Laboratory, Effects of Fuel Ethanol Use on Fuel-Cycle Energy and Greenhouse Gas Emissions, Paper # ANL/ESD-38, January 1999.**

- GREET Lifecycle Emissions Model was updated to account for improved efficiencies in corn & biomass farming; model was run to determine full-fuel-cycle GHG emissions, petroleum, and total fossil energy use for CG, E10, E85 and E95.
- Assumed up to 10% increase in fuel economy with E95.
- Assumed farmland conversion (from idle pastureland) for ethanol production will increase GHG by 57g/bu.
- Key variables are energy and chemical use intensity of farming practices, plant efficiency, and co-product valuation.
- Significant reductions in energy and GHG emissions with increasing ethanol content.
- Cellulosic ethanol production provided significantly higher reductions in energy and GHG emissions compared to corn-based ethanol. This result was largely due to an assumption that surplus electricity generated during biomass processing would offset conventional grid electricity.

**De Andrade, Jailson B., Andrade, Marta V., Pinheiro, Heloisa L.C., Atmospheric Levels of Formaldehyde and Acetaldehyde and their Relationship with the Vehicular Fleet Composition in Salvador, Bahia, Brazil, *J. Braz. Chem. Soc.*, Vol. 9, No. 3, 219-223, 1998.**

- The study showed that exhaust emissions from ethanol-fueled vehicles contain higher levels of acetaldehyde than formaldehyde. The opposite correlation is true for diesel-fueled vehicles.

# Appendix 3:

## References


AMERICAN ACADEMY OF PEDIATRICS: Fetal Alcohol Syndrome and Alcohol-Related Neurodevelopmental Disorders, PEDIATRICS Vol. 106 No. 2 August 2000, pp. 358-361.

American Coalition for Ethanol, ACE's State-by-State Ethanol Handbook: A 50-state guide to the U.S. ethanol industry.

American Coalition for Ethanol, "Environmental & Clean Air Benefits," http://www.ethanol.org/environment.html.

ACGIH (American Council of Governmental Industrial Hygienists) (1991) Documentation of the TLVs.

American Petroleum Institute (API), Backgrounder on Low Level Gasoline Blends Containing Ethanol (Blends containing Ethanol at concentrations up to 10% by volume), May 12, 2006.

California Air Resources Board (CARB), Staff Report: 2000 Zero Emission Vehicle Program, Biennial Review, August 7, 2000.

CARB, Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Public Hearing to Consider the Adoption of Exhaust and Evaporative Emission Control Requirements for small Off-Road Equipment and Engines Less Than or Equal to 19 Kilowatts, August 8, 2003. http://www.arb.ca.gov/regact/sore03/isor.pdf

CARB/CalEPA (California Air Resources Board & California EPA, Office of Environmental Health Hazard Assessment) (1999) Health and Environmental Assessment of the Use of Ethanol as a Fuel Oxygenate.

Carter, W.P.L., "Documentation of the SAPRC 99 Chemical Mechanism for VOC Reactivity Assessment," Draft report to the California Air Resources Board for Contracts No. 92-329 and 95-308, September 13, 1999. ftp://cert.ucr.edu/pub/carter/pubs/s99doc.pdf.

Connecticut DEP, Motor Vehicle Related Greenhouse Gas Emissions in Connecticut, A Report Pursuant to Public Act 06-161, December 2006.

Connecticut DEP, MTBE webpage at http://www.dep.state.ct.us/air2/mtbe/index.htm.

Connecticut DEP, 2002 Periodic Ozone and Carbon Monoxide Emissions Inventory, Final, December 2005.

The Consolidated Appropriations Act of 2004 (HR 2673, Section 428)

Coordinating Research Council (CRC), Fuel Permeation from Automotive Systems, CRC Project No. E-65, 2004.

CRC, Interim Report Summary: Fuel Permeation from Automotive Systems: E0, E6, E10 and E85, CRC E-65-3, 2006. Presented at CARB Fuels Workshop by Mike Ingham, 8/11/06.

CRC, Effects of Ethanol and Volatility Parameters on Exhaust Emissions, CRC Project No. E-67, January 30, 2006.

Crary, Brent, Effects of Ethanol on Emissions of Gasoline LDVs, TOYOTA Motor Corporation (Presentation at Toyota Technical Center, May 4, 2000).

Durbin, Thomas, Miller, Wayne, Younglove, Theodore, Huai, Tao, Cocker, Kathalena "Effects of Ethanol and Volatility on Exhaust Emissions: CRC E-67 Project," http://www.aqmd.gov/tao/ConferencesWorkshops/06_EthanolWS/04-TomDurbin_revised_background.pdf

The Energy Policy Act of 2005, Public Law 109-58, Title XV, Subtitle C, section 1541(b).

EPA Renewable Fuel Standard Program, Draft Regulatory Impact Analysis, September 2006.

EPA, RFG Consuming Areas on the East Coast, http://www.epa.gov/otaq/regs/fuels/rfg/rfgarea.pdf.

EPA, RFG Properties Survey Data: Information on Reformulated Gasoline (RFG) Properties and Emissions Performance by Area and Season, http://www.epa.gov/otaq/regs/fuels/rfg/properf/rfgperf.htm.

EPA website, "Federal and California Exhaust and Evaporative Emission Standards for Light-Duty Vehicles and Light-Duty Trucks," http://www.epa.gov/otaq/stds-ld.htm.

"The ethanol myth: *Consumer Reports'* E85 tests show that you'll get cleaner emissions but poorer fuel economy ... if you can find it," Consumer Reports, October 2006. Consumer Reports "The Ethanol Myth"

Ginsberg, G, Smolenski, S, Hattis, D and Sonawane, B (2002) Population distribution of aldehyde dehydrogenase-2 genetic polymorphism: implications for risk assessment. Regulatory Toxicol Pharmacol 36: 297-309.

Grosjean, D., Grosjean, E., Gunawardena, R., Rasmussen, R.A. (1998) Ambient Concentrations of Ethanol and Methyl tert-Butyl Ether in Porto Alegre, Brazil, March 1996-April 1997. Environmental Science & Technology, 32, 736-742.

HEI (Health Effects Institute) (1996) The Potential Health Effects of Oxygenates Added to Gasoline: A Review of the Current Literature.

Koshland, Catherine P., Sawyer Robert F., Lucas, Donald, and Franklin, Pamela, Evaluation of Automotive MTBE Combustion Byproducts in California Reformulated Gasoline, *Report to California State Legislature under S.B. 521: Effects of MTBE,* http://www.tsrtp.ucdavis.edu/mtberpt/vol3_1.pdf.

Kunitoh, S, Imaoka, S, Hiroi, T, Yabusaki, Y, Monna, T and Funae, Y. (1997) Acetaldehyde as well as ethanol are metabolized by human CYP2E1. J Pharmacol Exper Ther 280: 527-532.

National Petroleum Refiners Association, prepared by ExxonMobil, May 2006, http://www.npra.org/issues/fuels/state_bb/us_fuels_map.pdf.

National Research Council, "Ozone-forming potential of reformulated gasoline," (1999).

NEIWPCC/NESCAUM (New England Interstate Water Pollution Control Commission & Northeast States for Coordinated Air Use Management) Health, Environmental, and Economic Impacts of Adding Ethanol to Gasoline in the Northeast States, 2001.

NESCAUM, Relative Cancer Risk of Reformulated Gasoline and Conventional Gasoline Sold in the Northeast, Table ES-1 Method 3 Cancer Potency Ratios, 1998, p. ES-5.

NESCAUM, "Summary of NESCAUM Analysis Evaluating the NOx, HC, and CO Emission Reduction Potential from Adoption of the California Low Emission Vehicle (LEV II) Standards in the Northeast," October 2005.

Redding, B and Davidson, J M (2006) Ethanol fate and transport: An updated review of its impact on subsurface gasoline contamination. Paper presented at Umass Soils, Sediments and Water Conference.

Regulations of Connecticut State Agencies (R.C.S.A.) Sec. 22a-174-36b.

"Summary of NESCAUM Analysis Evaluating the NOx, HC, and CO Emission Reduction Potential from Adoption of the California Low Emission Vehicle (LEV II) Standards in the Northeast," October 2005.

Vasiliou V and Pappa A (2000) Polymorphisms of human aldehyde dehydrogenases. *Pharmacology* **61:** 192-198

# Appendix 4:

August 22, 2006

**Ethanol Health, Environmental and Energy Policy Documents**

Renewable Fuel Standard Program: Draft Regulatory Impact Analysis. EPA420-D-06-008. September 2006.
Link to Report

Lawrence Livermore National Laboratory, Cal EPA, California Air Resources Board: Health and Environmental Assessment of the Use of Ethanol as a Fuel Oxygenate 1999
Link to Report

Health Canada Report/Analysis of Ethanol Health Effects
Link to Health Canada Report

InterAgencyAssessmentofOxygenatedFuels-1997
Link to Inter Agency Report

The Health Effects Institute. Program Summary: Research on Oxygenates Added to Gasoline
Link to Health Effects Institute Report

Backgrounder on low Level Gasoline Blends Containing Ethanol, prepared by API (attached)

California Environmental Protection Agency Air Resources Board Draft Report (CARB): A Summary of the Staff's Assessment Regarding the Effect of Ethanol in California Gasoline on Emissions February 2005
Link to CARB Report

Coordinating Research Council (CRC), Inc. Project No. E-65: Fuel Permeation From Automotive Systems. Final Report, September 2004.
Link to CRC Report

Coordinating Research Council (CRC), Inc. Project No. E-67: Effects of Ethanol and Volatility Parameters on Exhaust Emissions. Final Report, January 2006.
Link to CRC Report

Coordinating Research Council (CRC), Inc. Project No. E-65-3: Fuel Permeation From Automotive Systems: E0, E6, E10 and E85. Interim Report, August 2006.
Link to CRC Report

Northeast States for Coordinated Air Use Management (NESCAUM): Health Environmental and Economic Impacts of Adding Ethanol to Gasoline in the Northeast States Volumes 1 and 2. July 2001.
Link to NESCAUM Report

Northeast States for Coordinated Air Use Management (NESCAUM): RFG/MTBE Issues and Options - Phase II. August 1999.

Congressional Research Service (CRS): Fuel Ethanol: Background and Public Policy Issues. Report March 3, 2006.
Link to CRS Report

Congressional Research Service (CRS): "Boutique Fuels" and Reformulated Gasoline: Harmonization of Fuel Standards. Report Updated May 10, 2006.
Link to CRS Report

Congressional Research Service (CRS): Alternative Fuels and Advanced Technology Vehicles: Issues in Congress. Report Updated May 8, 2006.
Link to CRS Report

Congressional Research Service (CRS): Energy Tax Policy. Report Updated May 26, 2006.
Link to CRS Report

Congressional Research Service (CRS): Agricultural-Based Renewable Energy Production. Report Updated May18, 2006.
Link to CRS Report

Congressional Research Service (CRS): Alternative Transportation Fuels and Vehicles: Energy, Environment and Development Issues. Report Updated January 7, 2005.
Link to CRS Report

United States Congress: Energy Policy Act of 2005 Title XV – Ethanol and Motor Fuels. Signed by President August 8, 2005.
Link to Energy Policy Act of 2005

California Air Resources Board: The Ozone Impact of Permeation VOC Relative to Carbon Monoxide. March 2006.

California Energy Commission (CEC): Alcohol Fuel Flexibility Progress and Prospects. September 2005.
Link to CEC Report

United States Environmental Protection Agency: Report to the President: Task Force on Boutique Fuels. June 2006.
Link to CEC Report

# Appendix 5

## Analysis of Recommendations

### The NESCAUM and NEIWPCC 2001 Report

In July 2001, the NESCAUM and the NEIWPCC issued a report entitled *Health, Environmental, and Economic Impacts of Adding Ethanol to Gasoline in the Northeast States*.[79] This report provided NESCAUM's member states with timely policy guidance, but noted that if actions were taken that changed available gasoline formulations, including use of additives other than ethanol to gasoline, further analysis may be needed to evaluate such plans. The report recommended that Northeast states develop coordinated, consistent analytical methods for implementation of programs to monitor ethanol impacts on air and water quality. It was made clear that MTBE should be phased out as a gasoline oxygenate. Furthermore, NESCAUM recommended that Congress remove the oxygen requirement for RFG and, pending congressional action, that EPA should grant state requests for oxygenate waivers.

With regard to health issues, the report found that direct exposure to ethanol in air and water supplies was not expected to pose public health risks but more study would be needed to estimate effects of exposure to toxic constituents such as PAN and acetaldehyde. The report concluded that air toxic and ozone precursor emissions could increase if ethanol replaces MTBE, but air quality benefits will still be significant compared to conventional gasoline because GHG benefits of CO reductions from ethanol will partially offset adverse ozone impacts and air toxic emissions. Low-level ethanol contamination of groundwater (less than 400 μg/L) was not expected to produce a significant health risk in terms of elevated blood alcohol and, because it degrades quickly, ethanol poses significantly less risk to water resources than MTBE.

The DEP and DPH have reviewed this report and continue to support its recommendations. As an integral component of the DEP's air quality management program to ensure protection of public health, the DEP continues to monitor the ambient air for ozone precursors. DEP will continue to evaluate monitoring data to assess any changes in environmental quality that could be attributed to this use of ethanol. DEP and DPH will continue to coordinate on these assessment efforts. Connecticut implemented the recommendation that MTBE should be phased out by passing the ban on sale of MTBE as a gasoline additive, which was effective January 1, 2004. The passage of EPACT, which included removal of the requirement for oxygenates in fuel, effectively implemented the report's recommendation that EPA grant state requests for a waiver from the oxygenate requirement.

---

[79] NEIWPCC and NESCAUM, Health, Environmental, and Economic Impacts of Adding Ethanol to Gasoline in the Northeast States, July 2001.

# Appendix 6

American Petroleum Institute (API)
May 12, 2006

**Backgrounder on Low Level Gasoline Blends Containing Ethanol**
**(Blends containing Ethanol at concentrations up to 10% by volume)**

## Introduction

Ethanol (ethyl alcohol) is an alcohol made by fermenting and distilling simple sugars. Ethyl alcohol is in alcoholic beverages and it is denatured (made unfit for human consumption) with the addition of 25% gasoline by volume when used for fuel. Fuel ethanol can be either anhydrous (containing less than 1% water which is the typical case in the US) or hydrous (containing at least 5% water by volume which is the typical case in Brazil). Fuel ethanol may also be produced from three classes of feedstocks: grains (corn, sorghum, wheat, etc), sugars (sugar cane and beets) or cellulosic material (switch grass, rice straw, wood, vegetable and forestry waste and other organic matter). (1, 2)[80]

The initial stimulus to ethanol production in the mid1970s was the drive to develop alternative supplies of motor fuel in response to the oil embargoes of 1973 and 1979. Prior to the passing of the Clean Air Act of 1977, there were no federal or state regulations controlling the use or properties of fuels containing alcohols. Gasolinealcohol blends were marketed in the 1930s and 1940s in Nebraska and surrounding farm states. Historically, a primary impetus to fuel ethanol production has come from corn producers anxious to expand the market for their crop. From1974 to 1977, a blend of 10% by volume ethanol and 90% by volume gasoline, was tested in Nebraska. In 1978, the Nebraska Gasohol Commission commercially introduced this fuel, thus beginning the broader use of ethanol as a fuel component.

In the late 1980s some states and urban areas began to use ethanol and other oxygenates in mandatory oxygenated fuel programs to reduce automobile tailpipe emissions of carbon monoxide (CO). Fuel oxygenates, such as ethanol, add oxygen to the fuel, which promotes more complete combustion thereby lowering CO emissions. Hydrocarbon (HC) exhaust emissions are also often reduced, but to a lesser degree. More recently, as vehicle emissions control technology grows more sophisticated, the effect of fuel oxygen content on CO emissions has diminished substantially. As discussed further below, ethanol produces somewhat lower greenhouse gas (CO2) emissions relative to petroleum fuels on a wells-to-wheels basis.

Production of fuel ethanol was encouraged by a partial exemption from the motor fuels excise tax. The Clean Air Act Amendments of 1990 also stimulated fuel ethanol production by requiring the implementation of: (a) oxygenated fuels programs beginning in November 1992 to reduce wintertime motor vehicle emissions of carbon monoxide (CO) in many CO nonattainment areas, and (b) reformulated gasoline (RFG) beginning January 1, 1995 to reduce emissions of ozone precursors and air toxics in certain ozone nonattainment areas. The stimulus for fuel ethanol production for RFG was because RFG was required to contain a minimum of 2% oxygen by weight. (The number of wintertime oxygenated fuels programs has declined in recent years as the number of areas out of attainment with the CO national ambient air quality standards has

[80] Numbers in ( ) denote references listed at the end of this paper.

dropped substantially. However, the reformulated gasoline program covers localities in 17 states and the District of Columbia – or about 30% of the gasoline sold in the US.) (3)

Until recently, RFG was required to contain a minimum of 2.0 weight percent oxygen (on average).[81] Ethanol has recently become the oxygenate most widely used in reformulated gasoline. This is in part due to the fact that the other commonly used oxygenate, MTBE, has been banned in 25 states. While ethanol has been blended in gasoline at levels of 5.7 percent and 7.7 percent by volume, it is more frequently blended at the 10 volume percent level to take maximum advantage of available tax credits. Ethanol may not be blended into gasoline in amounts over 10% by volume for use in conventional vehicles equipped with spark ignition engines. (i.e., vehicles that are not defined as "alternative fuel vehicles" per the 1992 Energy Policy and Conservation Act.) To do so would require an EPA determination that use of ethanol over 10% by volume would not cause or contribute to the failure of any vehicle to comply with emission standards over its useful life. (Section 211(f) of the Clean Air Act, 42 USC Section 7545(f))[82]‡ (Note: this requirement does not pertain to E85 which is not defined as gasoline and can only be used in vehicles that have been specifically designed to operate on this fuel.)

The requirement to use oxygen in RFG was replaced by a Renewable Fuels Standard (RFS) in the Energy Policy Act of 2005. The RFS requires an increasing amount of renewable transportation fuel use beginning with a 4.0 billion gallon per year usage requirement in 2006 and escalating to 7.5 billion gallons of annual usage requirement in 2012. While some of this requirement will be met with biodiesel and from cellulosic ethanol, it is anticipated that the greater majority of the requirement will be met in the short term with ethanol produced from corn due to its much wider availability.[83]

## Ethanol Production, Capacity and Technology

As mentioned above, fuel ethanol is often classified by its water content. "Hydrous" ethanol contains at least 5% water by volume. Hydrous ethanol is typical of the ethanol produced in Brazil. "Anhydrous" ethanol (typical of the fuel produced in the US) is manufactured using additional processing to further dehydrate the product to conform to ASTM D4806 specifications.[84] (4) These specifications limit the maximum water content to 1% by volume for denatured ethanol blended with gasoline for use as an automotive spark ignition engine fuel. The US is the world's largest fuel ethanol producer with Brazil being a close second. (5) As of March 2006, total current US ethanol annual production capacity is 4.4 billion gallons with about 2 billion gallons of additional capacity expected to come on line from plants currently under construction or via expansions. At present (March 2006) 96 ethanol plants are in production, 33

---

[81] On February 14, 2006, the US EPA issued two Direct Final Rules to remove the oxygen content requirement for (a) RFG sold nationally (effective on May 6, 2006) and (b) RFG sold in California (effective 60 days from date of publication of the rule in the *Federal Register*.

[82] In May 2005, Minnesota enacted a law which could mandate the use of gasoline blended with ethanol at 20% by volume starting in August 2013 if the use of E10 and E85 has not brought the total amount of fuel ethanol consumption up to 20% of the total supply by December 31, 2010. However, implementation of the law is contingent upon receipt of an EPA waiver under Section 211(f) of the Clean Air Act.

[83] The Energy Policy Act of 2005 requires 250 million gallons of ethanol derived from cellulosic feedstocks be blended into gasoline annually starting in 2013 and grants extra credit to this product: a gallon of cellulosic ethanol counts as 2.5 gallons of renewable fuel under the Renewable Fuel Standard (RFS).

[84] Note: Brazil produces both types and uses anhydrous at 25% by volume with gasoline.

facilities are being constructed and 9 are undergoing expansion, according to the Renewable Fuels Association. (6) In 2005, the US produced 3.9 billion gallons of ethanol and net imports amounted to 125.6 million gallons – mostly from nations in the Caribbean basin. (7)

**Corn-Based Ethanol:** Ethanol is produced largely in the Midwest, with over 80% of the current production capacity located in five states: Illinois, Iowa, Nebraska, Minnesota and South Dakota. The top five corn-producing states in the U.S. also are among the top producers of ethanol. In fact, over 99% of the current fuel ethanol production capacity in the US is based on the use of corn as the principal feedstock. (6) The US Department of Agriculture has estimated that 1.6 billion bushels of corn will be used to produce 4.3 billion gallons of fuel ethanol during 2005/2006 crop season (September 2005 – August 2006). This is equivalent to a yield of about 2.7 gallons of ethanol per bushel of corn. During the 2005/2006 crop season about 14.4 percent of the nation's corn crop production (11.1 billion bushels) went into the manufacture of ethanol. (8)

According to the Renewable Fuels Association, in 2005 "dry" milling plants (which use a grinding process) accounted for 79% of the fuel ethanol production capacity and "wet" milling plants (which use a chemical extraction process) accounted for the balance (21%). (5) The two processes differ with respect to the byproducts produced in conjunction with the conversion of the corn feedstock to ethanol. Use of the "dry" milling process results in distillers dried grain and soluble byproducts which are competitive with soybean meal as an animal feed. The "wet" milling process produces corn gluten feed, corn gluten meal, and corn oil as byproducts and these are generally used as livestock and poultry feed. The choice between the two processes is largely dependent upon the manufacturer's ability to market byproducts

Both the "dry" and "wet" milling processes use the following basic steps: First, the corn is processed, with various enzymes added to separate fermentable sugars. Next, yeast is added to the mixture for fermentation of the sugar to make alcohol. The alcohol is then distilled to fuel-grade ethanol that is 85-95% pure. Then, usually with the use of a molecular sieve, the fuel ethanol is further dried to contain less than 1 volume percent water. Finally, the ethanol destined for fuel and industrial purposes is denatured with a small amount of gasoline to make it unfit for human consumption. (5)

**Cellulosic Ethanol:** Ethanol can be produced from a variety of cellulose or biomass feedstocks such as wood, corn stover, switch grass and municipal solid wastes. One of the primary motivations behind efforts to develop cellulosic ethanol is the greater abundance, geographic dispersion, and low cost of the basic raw material feedstocks. However, there are significant technical and economic issues with both the acid and enzymatic-based processes that use these biomass feedstocks. Cellulose to ethanol production is still in the research and development phase and has seen only limited commercial application – on a pilot plant scale – to date. For instance, a bioenergy corporation in Canada is producing 1 million gallons/year of cellulosic ethanol from their Ottawa facility, but it is reportedly operating at only 25% of capacity and all of the output is being sold to the Canadian government. (5)

The biggest challenges in using cellulose as a feedstock lie in the treatment and disposal of process waste and in the conversion of complex sugars (hemicellulose). Cellulose is difficult to dissolve and hydrolyze and the sugars produced are not fermentable with normal yeasts. Because of the low value density of the raw materials, supply and front-end processing must be done on a major scale, requiring large capital investments. (1, 2, 10, 11, 12)

Lignin is a major byproduct of ethanol from cellulose and there is no ready market for this material. Because it does not readily break down into simple sugars, lignin is burned to produce energy for the ethanol plant or gasified to produce a syngas. Unlike corn-based processes which produce byproducts such as distillers grain with relatively low waste disposal needs, cellulosic processes are typically effluent and waste treatment intensive.

A 2000 study sponsored by the US Dept of Agriculture and the National Renewable Energy Laboratory estimated a 70% increase in production costs with large scale ethanol from cellulosic feedstocks compared to ethanol produced from corn. (11)

## Physical Properties of Ethanol

Ethanol is a flammable, colorless liquid with a faint alcohol odor. The properties of neat ethanol are shown in Appendix A and are compared with those representing nonoxygenated gasoline with 100% hydrocarbon content. Ethanol differs significantly from gasoline with respect to heating value, water solubility, heat of vaporization, boiling point, vapor pressure, flammability, flash point and antiknock performance. (13) The ability of ethanol to form azeotropes with gasoline hydrocarbons due to its molecular polarity means that the characteristics of the mixture into which it is blended will be significantly modified. The principal changes in the fuel properties due to the addition of ethanol to gasoline include:

- Increased Octane Number
- Greater fuel volatility (V/L ratio, Reid Vapor Pressure,[85] and distillation properties)
- Leaner fuel/air ratios
- Reduced fuel economy
- Increased water solubility along with the potential for phase separation.

Over the past 3-4 decades, a substantial body of literature has accumulated relating to analyses of the physical properties and characteristics of gasoline blends containing ethanol in concentrations up to 10 % by volume and the influence of these property effects on the performance of motor vehicles. For a comprehensive summary and analysis of the literature, the reader is encouraged to review Reference No.1: *Alcohols and Ethers: a Technical Assessment of Their Application as Fuels and Fuel Components*, API Publication 4261, Third edition, June 2001.

## Uses of Fuel Ethanol

Fuel ethanol is used mainly as a low concentrate blend component (5.7 to 10 percent by volume) in gasoline. In 2004, fuel ethanol accounted for about 2.4% of the total motor gasoline consumed in the US. (15) On an energy basis, fuel ethanol accounted for about 1% of total transportation energy use (including gasoline, diesel and jet fuel) in 2004. (16) Used in motor fuel, ethanol serves as: (a) an oxygenate (to reduce emissions of carbon monoxide and hydrocarbons), (b) a

[85] Note: Reid vapor pressure cannot be measured because the test method contains water. The test method used provides what is called dry vapor pressure equivalent or DVPE

dilutant to aid in the manufacture of reformulated gasolines, (c) an octane booster (to reduce tendency for both pre-ignition and engine knock), and (d) as an extender of gasoline supply.

Ethanol blended in gasoline at concentrations up to 10 percent by volume can be used in virtually all vehicles equipped with spark ignition engines manufactured since the early 1980s without any additional modification. In purer forms (i.e., blended in gasoline at concentrations of 85 percent by volume), ethanol can also be used as an alternative to gasoline in flexible-fueled automobiles especially designed for its use. However, ethanol used in this form currently accounts for only a small fraction (less than 1%) of total fuel ethanol consumption. (14)

**Effects of Ethanol-Gasoline Blends on Vehicle Emissions, Fuel Economy and Performance**

**Vehicle Emissions and Air Quality:** Adding oxygen to gasoline will enlean the air to fuel mixture of gases combusted in an engine. Combustion theory indicates that this leaning effect results in decreased exhaust emissions of carbon monoxide and hydrocarbons and increased exhaust emissions of nitrogen oxides. (17) These trends have generally been supported by empirical data. Several studies have shown that the use of gasoline with ethanol at concentrations of up to 10% by volume typically reduces exhaust emissions of carbon monoxide and hydrocarbons. The effect on exhaust emissions of nitrogen oxides is more variable, but has been shown generally to increase. (18-27)

Adding ethanol to gasoline (in amounts ranging from less than 1% by volume to over 10% by volume) increases the volatility (Reid Vapor Pressure) of the resulting blend by as much as 1 psi. This increase in vapor pressure due to the addition of ethanol typically results in higher evaporative hydrocarbon emissions. (1,19,24) Results reported from the Auto/Oil Air Quality Improvement Research Program (AQIRP) showed that a 10 % by volume ethanol blend increased diurnal emissions by 30% and hot soak emissions by 50%. The Auto/Oil AQIRP also found that for either gasolines or gasoline-ethanol blends, diurnal emissions were lowered by 50% by a vapor pressure reduction of 1 psi (the magnitude of vapor pressure increase caused by splash blending 210 volume percent ethanol into gasoline). (19)

Gasoline-ethanol blends have been shown to reduce benzene emissions. For instance, the Auto/Oil AQIRP reported that a 10% by volume ethanol blend reduced benzene emissions by 11.5%, almost the same magnitude as the dilution effect of ethanol in the fuel. However, emissions of acetaldehydes were more than doubled by the use of 10% by volume ethanol. (19)

The findings from a recent study of modern technology vehicles sponsored by the Coordinating Research Council (CRC) confirm that exhaust emissions when using gasoline-ethanol blends are mixed— showing reductions in some pollutants and increases in others. (27) The results also show that the impact of ethanol in some cases varied depending on the blend's distillation properties and ethanol content.[86] This study measured exhaust emissions on 12 California-certified 200-12003 model year light-duty vehicles on a matrix of 12 fuels with 3 levels of ethanol (0, 5.7 and 10% by volume), T50 (195, 215 and 235° F) and T90 (295, 330 and 355° F). The results showed the following:

[86] Both distillation and ethanol parameters are important inputs to the Predictive Model used in California to certify the emissions performance of Cleaner Burning Gasoline and the federal Complex Model used by the EPA to certify the emissions performance of federal RFG

- The effect of changes in ethanol content on Non-Methane Hydrocarbon emissions was dependent upon the T90 distillation temperature of the fuel. Non-methane hydrocarbon emissions increased with increasing ethanol content at mid and high levels of T90 but were unaffected at a low T90 level. This is somewhat in contrast to studies in the literature which (although not focusing on interactions) have reported decreasing hydrocarbon emissions with increases in ethanol content. However, many of the studies in the earlier literature used improper methods for measuring HC emissions, which overstated NMHC increases.

- CO emissions were significantly influenced by both the ethanol content of the fuel and by an interaction between ethanol and T50. The magnitude of the reductions (6 to 16% depending on T50 level) in going from zero to 10% by volume ethanol was comparable to that observed in the Auto/Oil AQIRP study on older (1989) technology vehicles. However, the CRC study showed that most of the CO benefit occurred as ethanol was increased from zero to 5.7% by volume. Increasing ethanol from 5.7% by volume to 10% by volume produced little to no change in CO at the low and midpoint levels of T50, and increased CO at the high level of T50.

- The effect of changes in ethanol content on NOx emissions was dependent upon the T50 distillation temperature of the fuel. When evaluated at the midpoint of the typical range for T50, NOx emissions were largely unaffected when the ethanol content in gasoline was increased from zero to 5.7% by volume, but increased when the ethanol content was raised to 10% by volume. However, at high levels of T50, NOx emissions were largely unaffected by the presence of ethanol at concentrations up to 10% by volume. The results in the literature show some tendency for NOx emissions to increase with greater ethanol levels, but this trend is not consistent or statistically significant over a wide range of studies.

- Mobile source air toxics, especially acetaldehyde emissions, increased when ethanol content was raised from zero to 10% by volume.

Ethanol blended gasoline increases the permeation of fuel hydrocarbons through the fuel system components of motor vehicles – contributing to the inventory of atmospheric ozone precursors. (28) The effect of ethanol on permeation is not currently represented in emissions inventory models. A recent report concluded that on-highway inventories of volatile organic carbon (VOC) emissions for the geographic areas studied would increase by 2 – 5% if the effect of ethanol on permeation was included. (29)

A 1999 study by the National Research Council concluded that while RFG leads to air quality improvements, the presence of oxygen in RFG may have little overall impact on ozone formation. (30) Air quality modeling studies have shown the benefits of gasoline blended with 10% by volume ethanol to be marginal at best. In some areas, the use of 10% by volume ethanol blends may actually increase ozone due to the local atmospheric conditions. (31) The state of California, for example, argued in an April 12, 1999 waiver petition to the EPA that the oxygen requirement in RFG increased NOx emissions which are ozone and PM precursors – and thereby interfered with its ability to attain the ozone and PM national ambient air quality standards. (32)

**Fuel Economy:** The heating value of neat ethanol is two thirds of that for typical gasoline. For gasoline blends containing 10% by volume ethanol, the heating value is about 3.4 percent lower than for a typical gasoline. (1) This difference in heat content is reflected in a small loss in fuel economy performance for vehicles operated on gasoline-ethanol blends. Based on measurements made by the Auto/Oil Air Quality Improvement Research Program, the fuel economy loss for a fleet of model year 1989 vehicles operated on gasoline containing 10% by volume ethanol was 2.6%. (33) Recent data published by the Coordinating Research Council on a fleet of 12 California-certified model year 2001-2003 cars and light trucks suggests that the fuel economy penalty for 10% by volume ethanol blend is on the order 1.4%. (27)

**Performance:** Driveability is a qualitative measure of a vehicle's ability to operate properly – under both cold start and hot ambient conditions. The addition of 0 to 10% by volume ethanol to gasoline impacts a vehicle's cold start and warm-up driveability score as indicated by the Driveability Index (DI) in the ASTM International (formerly the American Society for Testing and Materials) D 4814, *Standard Specification for Automotive Spark Ignition Engine Fuel*.[87] (34) For example, adding 5.7% by volume ethanol to hydrocarbon-only gasoline lowers the midrange volatility which in turn reduces the calculated DI by about 45 units on average. However, the resulting blend does not perform like a fuel with the DI lowered that much and thus the calculated value needs to be adjusted to correlate with actual cold start and warm-up performance. Currently the ASTM is balloting a proposal to change the DI equation in D 4814 with the addition of an upward adjustment of 2.4 times the ethanol volume content (when °F units are being reported for the D 86 distillation).

Ethanol addition to hydrocarbon-only gasoline can adversely affect vapor lock and hot-fuel handling driveability under hot ambient conditions. The single volatility property to best correlation with hot fuel problems is the temperature for a vapor-liquid ratio of 20 (T V/L=20). The addition of 5.7 vol % ethanol drops T V/L=20 about 20°F. Even at equal T V/L=20, ethanol blends do not perform as well as hydrocarbon-only gasoline. ASTM is studying an ethanol adjustment to T V/L=20, but has asked for some additional studies to be performed before preparing a ballot.

**Ethanol Lifecycle Energy Use and Greenhouse Gas Emissions**

While the range of estimates varies substantially, various studies have indicated that it takes approximately 73,500 Btu to produce a gallon of ethanol (mostly from fossil fuels). Given that the combustion of ethanol generates 76,000 Btu per gallon, and allowing for co-product credits, this implies that the net energy balance of ethanol is approximately 15,000 Btu per gallon. Hence, the size of the potential fossil fuel energy savings from ethanol use (on a well to wheels basis) is relatively small. (36)

[87] Customer satisfaction with the performance of a vehicle has been shown to be closely correlated with a quantitative score (Driveability Index) derived as a weighted sum of the frontend (T10), midrange (T50) and backend distillation properties of the fuel being used to operate it: DI = 1.5 * T10 +3*T50 + T90. (35)

Ethanol reduces greenhouse gas (CO2) emissions relative to petroleum fuels on a wells-to-wheels basis. The benefit is moderate (~13 percent) for corn-based ethanol today due to mitigating factors associated with increased emissions from fertilizer production and use, the operation of farm equipment and the transport of feedstocks and finished product. (37, 38)

While the greenhouse gas (GHG) benefit for cellulosic ethanol is expected to be substantially greater due to the lower intensity of fossil fuel use in the production process, this technology is not yet commercially available.

**Potential water issues associated with the use of gasoline/ethanol blends**

**Groundwater**: Releases of gasoline and gasoline containing 10% ethanol by volume (E10) are most likely to occur from the following sources: underground or aboveground storage tank systems (USTs/ASTs), and tanker truck or railcar accidents. (39, 40) In addition, small releases may occur from motor vehicle accidents where the fuel tank is damaged. Releases from storage facilities (USTs/ASTs) can be either single events (large or small releases) or chronic small releases over time. If releases do occur, it is expected that they will be detected soon and that appropriate corrective actions will be undertaken. For these reasons, E10 releases that might occur in the future would not be expected to result in any significant impacts to drinking water wells.

Concern with subsurface releases of E10 is mostly focused on the potential for migration of contaminants off site and/or to nearby drinking water wells. Gasoline blends containing up to 10% by volume ethanol have been in use for many years in the upper Midwest and other parts of the US. (41, 42)

Regarding benzene plumes, modeling and limited field studies suggest that benzene plumes from E-10 releases might be from 25% to >100% longer than from other gasoline formulations. (43-49) This potential benzene plume elongation effect would primarily be attributable to the preferential biodegradation of the larger dissolved mass of ethanol. In gasoline spills without ethanol where no corrective action is assumed, the small concentrations of benzene that dissolve from the spill are estimated to attenuate within about 150 – 300 feet of the source, although in some situations plumes have been shown to be much longer. Because ethanol is completely soluble in water, in an E10 spill to ground water most of the ethanol will almost immediately be dissolved and it will be present in concentrations much larger than benzene. Microorganisms will tend to biodegrade the ethanol instead of benzene. Small releases of E10 are not expected to migrate far from the source. (50, 51) The distance that dissolved ethanol or gasoline compounds will travel in ground water will be highly dependent upon the characteristics of the spill (e.g., the volume and rate of the release) and the local hydrogeology (e.g., ground water depth, velocity, geochemistry, etc.) and any corrective action undertaken.

While ethanol has the potential to enhance the solubility of benzene and other gasoline compounds in groundwater, for E10 this solubility effect is unlikely to have significant effects, perhaps increasing benzene solubility by less than 20%, if at all. (52, 53) Lab studies show however that fuels with >10% ethanol are much more likely to increase dissolved benzene or other gasoline components.

It would appear that because of the biodegradability and relatively low toxicity of ethanol, that the direct health or environmental impacts of the use of E10 are not likely to be greater than those of other current formulations of gasoline. (39, 40) Ethanol is relatively nontoxic and has a relatively high threshold for detection via taste, so it is not expected to degrade drinking water quality aesthetics. Methane is a byproduct of the biodegradation of ethanol, and has been shown to accumulate in the soil atmosphere at concentrations that could trigger safety concerns following a release of neat ethanol, depending on the release scenario. (54, 55)

Research is continuing so as to provide a more complete understanding of motor fuel releases involving E-10, and to identify the most appropriate corrective action technologies.

**Surface Water:** If there are large releases of E10 to streams, rivers or lakes, the rapid biodegradation of ethanol in surface waters could potentially result in the consumption of significant quantities of dissolved oxygen in the surface water body. (39, 40)

**Other environmental issues**

There is widespread consensus that the overwhelming majority of new ethanol that is produced to comply with the recently enacted renewable fuels standard will be corn-based, at least over the next decade. A recently completed study by Global Insight showed that higher levels of ethanol production lead to a greater degree of continuous corn planting, resulting in a greater need for weed control, more insect problems, and additional nitrogen fertilizer and insecticide use. (18)

Significantly higher fertilizer and pesticide use associated with higher corn crop-induced ethanol production levels will increase the likelihood of additional nutrient runoff and increased adverse environmental impacts on water resources.

U.S. corn production causes more total soil erosion, uses more herbicides, insecticides and nitrogen fertilizer than any other U.S. crop.

Atrazine, an herbicide used almost exclusively on corn, is EPA-classified as a possible carcinogen and is frequently found in drinking water supplies in the upper Midwest. The USGS reports that nationally, atrazine is found about 5 times more frequently than MTBE in drinking water.

In some Western irrigated corn acreage, ground water is being mined 25% faster than the natural recharge of its aquifer.

There are no definitive evaluations of health effects to ethanol exposures from its use in gasoline, e.g., the toxicity of gasohol tailpipe emissions or inhalation exposures during refueling. An extensive series of toxicity and exposure assessment studies is currently in progress as part of the EPA 211(b) testing program. Comprehensive evaluations several years ago by California and northeastern states indicated that replacement of MTBE by ethanol would have some unquantifiable benefits in terms of water contamination, but that such substitutions would have no substantial effects on public health impacts of air pollution. (39, 40)

**Impact of Increased Ethanol Usage on foreign oil imports**

Proponents of ethanol mandates often point out that its usage provides a direct benefit by reducing the nation's dependence on foreign oil imports. However, increasing ethanol production would not significantly reduce U.S. oil imports or provide any significant energy security benefit. Each gallon of gasoline blended with ethanol has less energy in it, requiring increased petroleum product imports to make up that energy loss. In addition, significant fossil fuel use is required to produce ethanol. Moreover, there also are refinery volume losses associated with ethanol-ready blend stocks due to the need to compensate for the increased RVP when ethanol is blended into gasoline. All of these factors result in a reduced impact on foreign imports, resulting in the displacement of only about 0.5 percent of crude oil imports even producing as much as 7.5 billion gallons of ethanol annually when the Renewable Fuels Standard is fully implemented in 2012.

**Increased Ethanol Production Creates Major Economic Disbenefits**

Global Insight recently completed a study which evaluated the major winners and losers from increased ethanol production. (36) The study drew the following conclusions:

- Increased ethanol production would divert more of the nation's corn crop away from food production, which would significantly increase food prices.
- Cow-calf producers, representing 42% of all farms, would suffer profit declines due to increased feed costs.
- Most of the economic benefit to the agriculture sector due to increased ethanol production would be limited to the producers of corn and soybeans, most of who operate in Nebraska, South Dakota, Minnesota, Wisconsin, Missouri, Indiana, Illinois and Ohio. Grain corn farmers represent about 16% of all farmers.
- Consumers abroad, especially poor countries, would also be worse off. Not only would they need to pay more for primary grains, but also there would likely be reduced food aid and other food donations as grain prices rise.

**Ethanol Supply and Infrastructure Issues**

95% of the nation's ethanol production is located in Midwestern states that must be transported to other regions at greater expense than gasoline, via truck, barge, or rail transport. In the near term, it is likely that most of the projected increase in shipments in ethanol to terminals will be handled by tanker truck and rail tank car as opposed to pipelines. Except for a few proprietary pipelines, the common carriers generally do not ship ethanol in their systems. The increased risk of corrosion and potential for water contamination associated with ethanol are key factors limiting its transport via pipeline.

**Tax Incentives, Subsidies and Mandates for Ethanol**

The Volumetric Ethanol Excise Tax Credit (VEETC) signed into law October 2004, allows blenders to claim a $0.51 per gallon tax benefit on each gallon of ethanol used. The VEETC replaces the former motor fuels tax exemption of 5.2¢ per gallon of E10 gasoline (52 cents/gallon of ethanol) that blenders of gasohol (E10) received from the 18.4¢ federal excise tax on motor fuels. There are various requirements under the IRS regulations issued for claiming the VEETC. (IRS, *Fuel Tax Guidance, IRS Notice 200504*, http://www.irs.gov/puh/irsdrop/n0504.pdf).

The 2005 Energy Policy Act expanded the definition of a small ethanol producer to include plants of up to 60,000,000-gallon annual production capacity. Plants defined as "small ethanol producers" are eligible for a production incentive of 10 cents per gallon on the first 15 million gallons of ethanol produced each year.

The corn used to produce fuel ethanol is also subsidized. In 2004, federal subsidies for US corn production totaled $4,501,951,045. (56) In addition, at least 14 states provide subsidies to ethanol producers, often at about 20 cents/gallon produced, up to a cap of $23 million per facility.

Domestic ethanol producers also enjoy some measure of protection from foreign suppliers via a tariff of 54 cents/gallon that is imposed on imports of ethanol and is targeted at lower cost producers such as Brazil.

Individual Midwestern states have a variety of programs in place to promote ethanol, including, for example, reduced ethanol blended motor fuel tax rates (North Dakota), motor fuel sales volume credits (Iowa), state infrastructure and production grants and credits, state fleet vehicle and refueling mandates, and flexible fuel vehicle registration and notification programs. Minnesota and Hawaii have statewide ethanol mandates. Montana recently established a statewide mandate for 10 volume percent ethanol that will be triggered when state ethanol producers make at least 55 million gallons annually. State legislatures in Colorado, Iowa and Missouri also have recently approved legislation adopting ethanol mandates and these bills await signature by their respective governors.

## REFERENCES (Appendix 6)


1. American Petroleum Institute, *Alcohols and Ethers: a Technical Assessment of Their Application as Fuels and Fuel Components*, API Publication 4261, Third edition, June 2001

2. Perlack, R. et al, Oak Ridge National Laboratory, *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion Ton Annual Supply*, DOE/GO1020052135, April 2005

3. US Environmental Protection Agency, Office of Transportation and Air Quality, *Reformulated Gasoline*, http://www.epa.gov/otaq/rfg.htm

4. ASTM International, *ASTM D 480603:Standard Specification for Denatured Fuel ethanol for Blending with Gasolines for Use as Automotive Spark-Ignition Engine Fuel*, http://www.astm.org/cgi-bin/SoftCart.exe/DATABASE.CART/HISTORICAL/D4806-03.htm?L+mystore+gosr5502

5. Renewable Fuels Association, *From Niche to Nation: Ethanol Industry Outlook 2006*, February 2006, http://www.ethanolrfa.org/objects/pdf/outlook/outlook_2006.pdf

6. Renewable Fuels Association, *US Fuel Ethanol Industry Plants and Production Capacity*, http://www.ethanolrfa.org/industry/locations/, accessed on 04/27/06.

7. Renewable Fuels Association, *Ethanol Industry Sets Record in 2005*, Press Release, February 27, 2006

8. Baker, A. and Allen, A., US Department of Agriculture, *Feed Outlook: Corn Used for Ethanol Production to Increase*, FDS06b, February 13, 2006, http://usda.mannlib.cornell.edu/reports/erssor/field/fds-bb/2006/fds06b.pdf

9. Renewable Fuels Association, *Fuel Ethanol – Industry Guidelines, Specifications, and Procedures (Publication #960501)*, Revised October 2005, www.ethanolrfa.org

10. National Renewable Energy Laboratory, *The Biomass Economy*, NREL/JA81031967, July 2002

11. McAloon, A., et al, National Renewable Energy Laboratory, *Determining the Cost of Producing Ethanol from Corn Starch and Lignocellulosic Feedstocks*, October 2000, NREL/TP58028893

12. DiPardo, J, US Energy Information Administration, *Outlook for Biomass Ethanol Production and Demand*, July 30, 2002, http://www.eia.doe.gov/oiaf/analysispaper/biomass.html

13. Owen, K. and Coley, T., *Automotive Fuels Reference Book*, 2nd ed., Society of Automotive Engineers, Inc.

14. Yacobucci, B., Congressional Research Service, *Fuel Ethanol: Background and Public Policy Issues*, March 3, 2006

15. US Federal Highway Administration, *Highway Statistics 2004*, http://www.fhwa.dot.gov/policy/ohim/hs04/htm/mf21.htm

16. US Energy Information Administration, *Monthly Energy Review*, February 2006, http://tonto.eia.doe.gov/merquery/mer_data.asp?table=T02.05

17. Heywood, J.J., *Internal Combustion Engine Fundamentals*, McGraw Hill, 1988

18. Koehl, W.J., et al., *Effects of Gasoline Composition and Properties on Vehicle Emissions: A Review of Prior Studies - The Auto/Oil Air Quality Improvement Research Program,* SAE Technical Paper No. 912321, Society of Automotive Engineers, 1991.

19. Reuter, R.M., et al, *Effects of Oxygenated Fuels on RVP on Automotive Emissions – Auto/Oil Air Quality Improvement Program*, SAE Technical Paper No. 920326, Society of Automotive Engineers, 1992.

20. Mayotte, S.C., et al., *Reformulated Gasoline Effects on Exhaust Emissions: Phase 1; Initial Investigation of Oxygenate, Volatility, Distillation, and Sulfur Effects*" SAE Technical Paper No. 941973, Society of Automotive Engineers, 1994.

21. Mayotte, S.C., et al., *Reformulated Gasoline Effects on Exhaust Emissions: Phase 2; Continued Investigation of the Effects of Fuel Oxygenate Content, Oxygenate Type, Sulfur, Olefins, and Distillation Parameters*, SAE Technical Paper No. 941974, Society of Automotive Engineers, 1994.

22. Korotney, D.J., et al., R*eformulated Gasoline Effects on Exhaust Emissions: Phase 3; Continued Investigation of the Effects of Fuel Oxygenate Content, Oxygenate Type, Sulfur, Olefins, and Distillation Parameters*, SAE Technical Paper No. 950782, Society of Automotive Engineers, 1995.

23. Alliance of Automobile Manufacturers (AAM) and the Association of International Automobile Manufacturers (AIAM), *AAM/AIAM Industry Low-Sulfur Test Program,* Presentation to the California Air Resources Board, www.arb.ca.gov/cbg/meeting/2001/mtg2001.htm, September 2001.

24. Crary, B., *Effects of Ethanol on Emissions of Gasoline LDVs,* Toyota Motor Corporation, Presentation to California Air Resources Board, www.arb.ca.gov/fuels/**gasoline**/carfg3/toyota_prstn.pdf, May 2000.

25. Colorado Department of Health, T*he Impact of a 10% Ethanol Blended Fuel on the Exhaust Emissions of Tier 0 and Tier 1 Light-Duty Gasoline Vehicles at 35 °F*, Aurora Vehicle Emissions Testing Center, January, 1999.

26. Aubin, K. and Graham, L., *The Evaluation of Ethanol – Gasoline Blends on Vehicle Exhaust and Evaporative Emissions: Phase 1,* Report by Environment Canada, Emissions Research and Measurement Division, October, 2002.

27. Durbin, T. et al, University of California at Riverside, College of Engineering, Center for Environmental Research and Technology*, Effects of Ethanol and Volatility Parameters on Exhaust Emissions*, CRC Project No. E67, January 30, 2006, http://www.crcao.org/

28. Haskew, H., et al., *Fuel Permeation from Automotive Systems*, CRC Project No. E65, September 2004, http://www.crcao.org/

29. Darlington, T., Air Improvement Resources, *Effects of Gasoline Ethanol Blends on Permeation Emissions Contribution to VOC Inventory From On-Road and Off-Road Sources*, Final Report, prepared for American Petroleum Institute, March 3, 2005

30. National Research Council, *The Ozone-Forming Potential of Reformulated Gasoline*, 1999

31. Wisconsin Department of Natural Resources, Bureau of Air Management, *Ozone Air Quality Effects of a 10% Ethanol Blended Gasoline in Wisconsin*, September 6, 2005.

32. Letter from California Governor Gray Davis to Carol M. Browner, Administrator, Environmental Protection Agency, April 12, 1999, http://www.arb.ca.gov/fuels/gasoline/oxy/oxywav.htm?PF=Y

33. Hochhauser, A.M., et al., *Fuel Composition Effects on Automotive Fuel Economy – Auto/Oil Air Quality Improvement Research Program,* Society of Automotive Engineers, Technical Paper 930138, 1993.

34. ASTM International, *ASTM D 4814: Standard Specification for Automotive Spark-Ignition Engine Fuel*,http://www.astm.org/cgi-bin/SoftCart.exe/DATABASE.CART/REDLINE_PAGES/D4814.htm?L+mystore+rcvv0799

35. Barker et al., *The Development and Proposed Implementation of the ASTM Driveability Index for Motor Gasoline*, Society of Automotive Engineers, Technical Paper 881668, 1988

36. Global Insight, *Winners and Losers of Ethanol Mandates*, May 2005, http://api-ec.api.org/filelibrary/Global%20Insight%20Final%20Ethanol%20Report%202005%20May.pdf

37. Farrell, A.E. et al., *Ethanol Can Contribute to Energy and Environmental Goals*, Science, 27 January 2006, vol 311

38. Wang, M. et al, General Motors Corp, Argonne National Laboratory, BP, ExxonMobil, Shell, *Well-to-Wheel Energy Use and Greenhouse Gas Emissions of Advanced Fuel/Vehicle Systems – North American Analysis*, June 2001

39. LLNL. 2001. *Environmental Assessment of the Use of Ethanol as a Fuel Oxygenate: Subsurface Fate and Transport of Gasoline Containing Ethanol*. October 2001 Lawrence Livermore National Laboratory. UCRLAR145380 Report to the CA State Water Resources Control Board http://www-erd.llnl.gov/ethanol/

40. NESCAUM. 2001. *Health, Environmental, and Economic Impacts of Adding Ethanol to Gasoline in the Northeast: Vol 1, Summary and Recommendations*. July 2001. Link to NESCAUM Report

41. Powers, S.E., Rice, D. W., Dooher, B., and Alvarez, P.J.J., *"Will ethanol-blended gasoline affect groundwater quality?"* Environ. Sci, Technol., 35, 24A30A (2001a).

42. Powers, S.E., Hunt, C.S., Hermann, S.E., Corseuil, H.X., Rice, D., and Alvarez, P.J.J, *"The transport and fate of ethanol and BTEX in groundwater contaminated by gasohol,"* Critical Reviews in Environmental Science and Technology, 31, 79123 (2001b). (also at: http://www.remas.ufsc.br/donwload/publicacao_06.pdf )

43. Niven, R.K., 2005. *Ethanol in gasoline: environmental impacts and sustainability review article*. Renewable and Sustainable Energy Reviews. 9(2005): 535555

44. Speidel, H.K. and I. Ahmed. 1999. *Biodegradability characteristics of current and newly-developed alternative fuels*. SAE 1999013518.

45. Deeb, R.A., Sharp, J.O., Stocking, A., McDonald, S., West, K.A., Laugier, M., Alvarez, P.J.J., Kavanaugh, M.C., and Alvarez-Cohen, L., *"Impact of Ethanol on Benzene Plume Lengths: Microbial and Modeling Studies,"* ASCE J. Env. Eng., 128, 868875 (2002).

46. Lovanh, N., Hunt, C.S., and Alvarez, P.J.J., *"Effect of ethanol on BTEX degradation kinetics: continuous culture experiments,"* Wat. Res., 36, 37393746 (2002).

47. Molson, J.W., Barker, J.F., Frind, E.O., and Schirmer, M., *"Modeling the impact of ethanol on the persistence of benzene in gasoline-contaminated ground water,"* Water Resources Research, 38, 41– 411 (2002).

48. Ruiz-Aguilar, G.M, O'Reilly, K., and Alvarez, P.J.J., *"A comparison of benzene and toluene plumes for sites contaminated with regular versus ethanol-amended gasoline,"* Ground Water Monitoring and Remediation, 23, 4853(2002a)

49. Ruiz-Aguilar, G.M, Fernandez-Sanchez, J.M., Kane, S.R., Kim, D. and Alvarez, P.J.J., *"Effect of ethanol and methyltertbutyl ether on monoaromatic hydrocarbon biodegradation: response variability for different aquifer materials under various electron-accepting conditions,"* Environ. Toxicol. Chem., 21, 26312639 (2002b)

50. API. 2003. *Evaluation of Small-Volume Releases of Ethanol-Blended Gasoline at UST Sites* Bulletin No. 19 October 2003 http://api-ec.api.org/filelibrary/19_Bull.pdf.

51. Dakhel, N.; Pasteris, G.; Werner, D.; Hohener, P. 2003. *Small-Volume Releases of Gasoline in the Vadose Zone: Impact of the Additives MTBE and Ethanol on Groundwater Quality*. Environ. Sci. Technol.; 2003; 37(10); 21272133

52. API. 2005. *The Impact of Gasohol and Fuel-Grade Ethanol on BTX and Other Hydrocarbons in Ground Water: Effect on Concentrations Near a Source* Bulletin No. 23 December 2005 http://api-ec.api.org/filelibrary/ACF1F7.pdf

53. He, X., and Rixey, W.G., *"Ethanol-Enhanced Dissolution of Aromatic Hydrocarbons from a Residually Trapped NAPL Source,"* Groundwater Monitoring and Remediation (2004).

54. McDowell, C.J., Buscheck, T., and Powers, S.E., *"Behavior of gasoline pools following a denatured ethanol spill,"* Groundwater, 41, 746757 (2003).

55. API. 2003. *Answers to Frequently Asked Questions About Ethanol Impacts to Groundwater*. API Bulletin No. 20 December 2003. http://api-ep.api.org/filelibrary/Bull20_052104.pdf

56. Environmental Working Group, *Farm Subsidy Database*. http://www.ewg.org/farm/progdetail.php?fips=00000&progcode=corn

# APPENDIX 6A

## Comparison of Fuel Properties[88]

| Property | Ethanol | Gasoline |
|---|---|---|
| **Chemical Formula** | $C_2H_5OH$ | $C_4$ to $C_{12}$ chains |
| **Molecular weight** | 46.07 | 100-105 |
| **Composition, weight %** | | |
| **Carbon** | 52.2 | 85-88 |
| **Hydrogen** | 13.1 | 12-15 |
| **Oxygen** | 34.7 | 0 |
| **Relative Density, 60/60°F** | 0.794 | 0.69-0.793 |
| **Density, lb/gal @ 60°F** | 6.61 | 5.8-6.63 |
| **Lower heating value** | | |
| **Btu/lb** | 11,500 | 18,000-19,000 |
| **Btu/gal @ 60°F)** | 76,000 | 109,000-119,000 |
| **Boiling Temperature, °F** | 173 | 80-437 |
| **Freezing point, °F** | -173.4 | -40 |
| **Vapor Pressure, psi** | 2.3 | 7-15 |
| **Blending Reid Vapor Pressure, psi** | 18 | 7-15 |
| **Octane (R+M)/2** | 98-100 | 86-94 |
| **Water solubility, @70°F** | | |
| **Fuel in Water, vol %** | 100 | Negligible |
| **Water in Fuel, vol %** | 100 | Negligible |
| **Flash point, closed cup, °F** | 55 | -45 |
| **Autoignition temperature, °F** | ~793 | ~495 |
| **Flammability limits, vol %** | | |
| **Lower** | 4.3 | 1.4 |
| **Higher** | 19.0 | 7.6 |
| **Latent heat of Vaporization** | | |
| **Btu/lb @ 60°F** | 396 | ~150 |
| **Btu/gal @ 60°F** | 2,378 | ~900 |
| **Stoichiometric air/fuel ratio, weight** | 9.00 | 14.7 |

Source: Reference 1

[88] American Petroleum Institute, *Alcohols and Ethers: a Technical Assessment of Their Application as Fuels and Fuel Components*, API Publication 4261, Third edition, June 2001

# Appendix 7

## Actions by Other States Regarding Use of Ethanol as a Gasoline Additive

***Regulatory Action***

**California** is the only state to have adopted a regulation setting a specific limit on the ethanol content of gasoline sold in the state. Section 2262 of the California Code of Regulations sets the ethanol limit at 5.7% due to concerns about increased $NO_X$ emissions from higher percentages. This regulation does make provisions for increasing the oxygenate content up 10%, if compliance with standards required for particulate matter alternate specifications, outlined in Section 2262 are met.

***Non-regulatory Actions***

Many states have initiated actions to develop their capability to use alternate energy. The following are a small subset of those actions. The United States Department of Energy has summarized these initiatives, which are available at http://www.eere.energy.gov/cleancities/ccn/progs/story.php/WHATS_NEW/635/0/A.

**Connecticut**

- Governor M. Jodi Rell proposed an energy program on September 18, 2006. The program promotes the use of biofuels and renewable energy. Some of these strategies include the following:
  - By 2020, 20% of all energy used and sold in the State of Connecticut will come from clean or renewable resources.
  - By 2020, state fossil fuel consumption will be reduced by 20%.
  - All commercial transportation fuels sold in the state will be required to include a mixture of 20% alternative fuels.
- The State of Connecticut owns a number of flexible fuel vehicles and E-85 is available to State fleet vehicles at two Department of Transportation (DOT) facilities.

**New York**

- New York is constructing a new $87 million ethanol production plant at the former Seneca Army Depot in Romulus, NY, which will be able to produce 50 million gallons of ethanol per year. The plant will be eligible to receive a state production tax credit of up to $2.5 million per year.

**Maryland**

- Maryland is planning to add two more E-85 fueling stations for its state fleet vehicles. Conversion of its state fleet to E-85 will occur over time through fleet rollover.

**Colorado**

- Colorado's legislature has recently passed legislation adopting a statewide ethanol mandate.

**Hawaii**

- Hawaii has a statewide ethanol mandate.

**Illinois**

- Illinois has awarded $25 million in grants to for construction of five new ethanol and biodiesel production plants with the expectation of producing 225 million gallons year of biofuels. The projects rely on $334 million in private investment.

**Iowa**

- Iowa has instituted motor fuel sales volume credits for ethanol blends and, more recently, Iowa's legislature has passed legislation adopting a statewide ethanol mandate.

**Minnesota**

- Minnesota has enacted a statewide ethanol fuel mandate.

**Missouri**

- Missouri's legislature has recently passed legislation adopting a statewide ethanol mandate.

**Montana**

- Montana has a statewide mandate for 10 % ethanol, by volume, to be triggered when state ethanol production reaches 55 million gallons per year.

**North Dakota**

- North Dakota has reduced its motor fuel tax rates for ethanol-blended fuels.

**Wisconsin**

- Wisconsin is issuing $50 million in bonds to support the Wisconsin Energy Independence (WEI) Fund with a goal of generating 25% of Wisconsin's electricity and 25% of its transportation fuel from renewable sources by 2025. It is expected that the fund will leverage an additional $100 million in investment from the private sector.
- The state is hoping to lure the nation's first cellulosic ethanol plant to Wisconsin by offering a $5 million grant.
- An additional $30 million will be allocated to the WEI of which $20 million would fund grants to companies and researchers developing new technologies. It is expected that the fund will leverage an additional $240 million from private sector investment.
- The governor has a goal of spurring job growth by capturing 10% of the renewable market by 2030 through the funding for the cellulosic plant and the research support.
- Wisconsin is providing additional funds as tax incentives for gas stations to invest in E-85 and biodiesel tanks and pumps; for businesses investing in bio-powered vehicles; or for venture capitalists investing in renewable technologies.

# Appendix 8

## Estimated Impact of Different Gasoline Blends on California South Coast Air Quality Parameters[89]

| | | 1997 MTBE | 2003 MTBE | 2003 Et2% | 2003 Et3.5% | 2003 Non-Oxy |
|---|---|---|---|---|---|---|
| Acetaldehyde (ppb) | | | | | | |
| *Population-Weighted Annual Exposure* | | | | | | |
| | Upper | 1.8 | 1.6 | 1.6 | 1.8 | 1.6 |
| | Lower | 1.8 | 1.5 | 1.5 | 1.7 | 1.5 |
| *Maximum Daily Average* | | | | | | |
| | Upper | 6.2 | 6.2 | 6.2 | 6.2 | 6.2 |
| | Lower | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 |
| *Maximum 1 Hour Average* | | | | | | |
| | Upper | 17.7 | 16.7 | 16.9 | 17.1 | 16.9 |
| | Lower | 13.8 | 13.1 | 13.2 | 13.4 | 13.2 |
| Benzene (ppb) | | | | | | |
| *Population-Weighted Annual Average* | | | | | | |
| | Upper | 1.19 | 0.80 | 0.78 | 0.81 | 0.76 |
| | Lower | 1.07 | 0.72 | 0.70 | 0.73 | 0.69 |
| *Maximum Daily Average* | | | | | | |
| | Upper | 9.5 | 6.8 | 6.5 | 6.8 | 6.4 |
| | Lower | 7.4 | 5.3 | 5.1 | 5.3 | 4.9 |
| *Maximum 1 Hour Average* | | | | | | |
| | Upper | 22.4 | 14.3 | 14.3 | 14.3 | 14.3 |
| | Lower | 11.6 | 7.4 | 7.4 | 7.4 | 7.4 |
| Butadiene (ppb) | | | | | | |
| *Population-Weighted Annual Average* | | | | | | |
| | Upper | 0.36 | 0.20 | 0.20 | 0.20 | 0.20 |
| | Lower | 0.34 | 0.19 | 0.19 | 0.19 | 0.19 |
| *Maximum Daily Average* | | | | | | |
| | Upper | 2.9 | 1.2 | 1.2 | 1.2 | 1.2 |
| | Lower | 2.0 | 0.8 | 0.8 | 0.8 | 0.8 |
| *Maximum 1 Hour Average* | | | | | | |
| | Upper | 6.7 | 3.4 | 3.4 | 3.4 | 3.4 |
| | Lower | 3.1 | 1.6 | 1.6 | 1.6 | 1.6 |
| Ethanol (ppb) | | | | | | |
| *Population-Weighted Annual Average* | | | | | | |
| | Best | 5.4 | 5.1 | 7.6 | 8.8 | 5.1 |
| *Maximum Daily Average* | | | | | | |
| | Upper | 51 | 49 | 71 | 81 | 49 |
| | Lower | 47 | 45 | 64 | 75 | 45 |
| *Maximum 1 Hour Average* | | | | | | |
| | Upper | 108 | 101 | 145 | 165 | 101 |
| | Lower | 78 | 74 | 114 | 140 | 74 |

[89] CARB/CalEPA, Health and Environmental Assessment of the Use of Ethanol as a Fuel Oxygenate, (1999), Vol. 3 (http://www-erd.llnl.gov/ethanol/etohdoc/vol3/vol3.pdf), page 35.

## Appendix 8 (continued)

| | | 1997 MTBE | 2003 MTBE | 2003 Et2% | 2003 Et3.5% | 2003 Non-Oxy |
|---|---|---|---|---|---|---|
| Formaldehyde (ppb) | | | | | | |
| *Population-Weighted Annual Average* | | | | | | |
| | Upper | 4.7 | 4.2 | 4.1 | 4.1 | 4.0 |
| | Lower | 4.7 | 4.1 | 4.0 | 4.0 | 4.0 |
| *Maximum Daily Average* | | | | | | |
| | Best | 14.0 | 12.2 | 11.8 | 12.1 | 11.7 |
| *Maximum 1 Hour Average* | | | | | | |
| | Upper | 37.8 | 38.3 | 37.8 | 38.1 | 37.8 |
| | Lower | 20.3 | 20.6 | 20.3 | 20.5 | 20.3 |
| MTBE (ppb) | | | | | | |
| *Population-Weighted Annual Average* | | | | | | |
| | Upper | 3.9 | 2.6 | 0 | 0 | 0 |
| | Lower | 3.6 | 2.4 | 0 | 0 | 0 |
| *Maximum Daily Average* | | | | | | |
| | Upper | 29 | 20 | 0 | 0 | 0 |
| | Lower | 13 | 9 | 0 | 0 | 0 |
| *Maximum 1 Hour Average* | | | | | | |
| | Upper | 67 | 46 | 0 | 0 | 0 |
| | Lower | 19 | 13 | 0 | 0 | 0 |
| PAN (ppb)[b] | | | | | | |
| *Maximum Daily Average* | | | | | | |
| | Upper | 5.0 | 4.8 | 4.8 | 4.9 | 4.7 |
| | Lower | 2.5 | 2.4 | 2.4 | 2.4 | 2.4 |
| *Maximum 1 Hour Average* | | | | | | |
| | Upper | 10.0 | 9.5 | 9.3 | 9.5 | 9.1 |
| | Lower | 5.0 | 4.8 | 4.7 | 4.8 | 4.5 |

**Appendix 8 (continued)**

| | 1997 MTBE | 2003 MTBE | 2003 Et2% | 2003 Et3.5% | 2003 Non-Oxy |
|---|---|---|---|---|---|
| Carbon Monoxide (ppm) | | | | | |
| *Maximum 8 Hour Average* | | | | | |
| Best | 17.5 | 14.3 | 14.3 | 13.4 | 14.7[c] |
| *Maximum 1 Hour Average* | | | | | |
| Best | 22.5 | 19.2 | 19.2 | 18.0 | 19.7[c] |
| Nitrogen Dioxide (ppm) | | | | | |
| *Maximum Annual Average* | | | | | |
| Best | 0.043 | CARB reported, "No difference expected among 2003 scenarios" [d] | | | |
| *Maximum Daily Average* | | | | | |
| Best | 0.117 | 0.098 | 0.097 | 0.097 | 0.097 |
| *Maximum 1 Hour Average* | | | | | |
| Best | 0.255 | 0.235 | 0.235 | 0.235 | 0.235 |
| Ozone (ppm) | | | | | |
| *Maximum 8 Hour Average* | | | | | |
| Best | 0.206 | 0.196 | 0.196 | 0.196 | 0.196 |
| *Maximum 1 Hour Average* | | | | | |
| Best | 0.244 | 0.230 | 0.228 | 0.228 | 0.228 |
| Particulate Matter (10 microns or less) ($\mu g/m^3$) | | | | | |
| *Maximum Annual Geometric Mean* | | | | | |
| Best | 56 | CARB reported, "No difference expected among 2003 scenarios" [d] | | | |
| *Maximum Daily Average* | | | | | |
| Best | 227 | CARB reported, "No difference expected among 2003 scenarios" [d] | | | |

[a] Source: Table 4.6 of "Staff Report: Air Quality Impacts of the Use of Ethanol in California Reformulated Gasoline. November 18, 1999. California Air Resources Board, Cal/EPA"

[b] A population-weighted annual average for PAN was not determined because consistent long-term measurements of atmospheri PAN have not been performed. See CARB report for details.

[c] This apparent increase is a function of the emission assumptions. Due to the wintertime oxygenate requirement for the SoCAB, concentrations within the nonattainment area of Los Angeles County will not differ from the 2003 MTBE baseline.

[d] No significant change compared to 1997 MTBE-fuel scenario. See CARB report for details.

# Appendix 9
# Public Participation and Comments

# State Implementation Plan Revision Advisory Committee
# (SIPRAC) Presentations
# September 2006

## Ethanol Study Report

SIPRAC
September 14, 2006

## Ethanol Study Report to Legislature

- An Act Concerning Protection of Public Water Supply Resources: Public Act 06-53 Section 6.
- Due on December 31, 2006.
- DEP to study effect on Connecticut's air quality of using ethanol in gasoline.
  - Effect on emissions and attainment of NAAQS
- DPH to study health implications.

## Ethanol Study Report Requirements

- Update NESCAUM/NEIWPCC reports.
- Analysis of whether to continue use.
- Effect on air quality.
- Update on other states' actions.
- Recommendations for alternative or supplemental emission reduction opportunities.
- Must be completed within available resources, no funding appropriated.

## What is Ethanol?

- Alcohol: $C_2H_5OH$-denatured.
- Originally added to gasoline as an oxygenate.
- Oxygenates promote more complete fuel combustion.
- Increases octane.

## Why We Have Ethanol in Connecticut

- Originally MTBE used as octane enhancer.
- 1992: Served as a CO control measure.
- 1995: Suppliers added MTBE to meet oxygenate requirement.
- Concerns with groundwater contamination.
- January 1, 2004 statutory ban prohibiting sale of MTBE as a gasoline additive: Public Act 03-122.
- Ethanol was only viable option to meet oxygenate requirement.

## Ethanol in Connecticut Gasoline

- Refiners choose to blend ethanol at 10% by volume (3.5% oxygen by weight).
  - Federal Tax Incentives
  - 5.7% ethanol by volume complies with 2.0% oxygen
- Connecticut and other New England states currently have a 10% Ethanol blend.

## Energy Policy Act of 2005

- Signed into law August 8, 2005.
- Eliminated RFG 2.0% Oxygen by weight requirement.
  - Effective May 6, 2006
- Eliminated oxygenate requirement waiver process.
- Introduction of Renewable Fuels Standard (RFS).
  - Designed to reduce dependence on foreign oil

## Renewable Fuels Standard (RFS)

- 2.78% of fuel sold in 2006 must be from renewable sources (4.0 billion gallons).
- EPA announced rulemaking proposal to increase to 3.71% for 2007 (4.7 billion gallons).
- By 2012, RFS increases to 7.5 billion gallons.

## Ethanol Production

- ~100 ethanol plants in US.
- Producing 4.8 billion gallons ethanol in 2006.
- 46 new ethanol plants under construction.
- 140 billion gallons gasoline used in the US/year.

## Existing Studies for Consideration

- No funding was provided for this study.
- Efforts focused on existing studies to inform the General Assembly on issue.
- Several studies by CARB and Coordinating Research Council (CRC) that looked at HC, NOx and toxics.

## California Ethanol Studies 2002 Fuel Permeation

- In 2002 CARB and CRC co-funded permeation study.
- Permeation is diffusion of fuel through rubber and plastic components of fuel and fuel vapor systems.
- 3 Fuels studied:
  - 11% volume MTBE
  - 5.7% volume ethanol
  - Non-oxygenated

## California Ethanol Studies 2002 Fuel Permeation

- Permeation Results.
  - All vehicles ethanol > MTBE
  - Most vehicles ethanol > non-oxygenated
  - 65% or 1.4 grams/day more than MTBE fuel
  - 45% or 1.1 grams/day more than non-oxygenated fuel
  - 2X increased permeation for each 10° C rise in T
  - Ozone reactivities very similar for all 3 fuels
    - MTBE and ethanol statistically equal
    - Non-oxygenated statistically higher than MTBE and ethanol

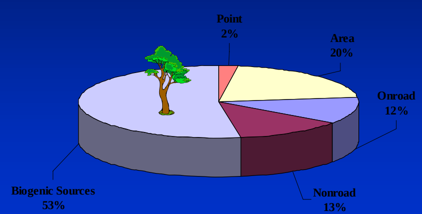
## California Ethanol Studies
## 2005 Fuel Permeation

- Additional study building on 2002 results.
- Stakeholder process ongoing.
- Final report expected, no release date yet.
- Investigated 5 fuels:
  - E0 – Non-oxygenated base
  - E6 – 5.7 volume % Ethanol
  - E6Hi – 5.7 volume % Ethanol with increased aromatics
  - E10 – 10 volume % Ethanol
  - E85 – 85 volume % Ethanol

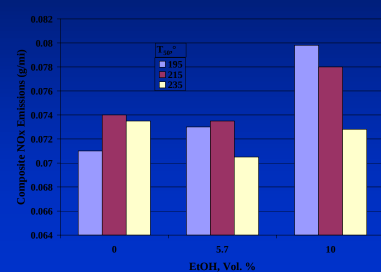
## California Ethanol Studies
## 2005 Fuel Permeation

- Modeling total evaporative emissions shows additional 25 TPD of HC in CA from 10% ethanol.
- Roughly equivalent to 2.5 TPD for CT; 0.33% of inventory.
- Future review required of other studies and the impact of the RFS rulemaking.

## 2002 Connecticut Emission Inventory
## VOC: 752 Tons per Day

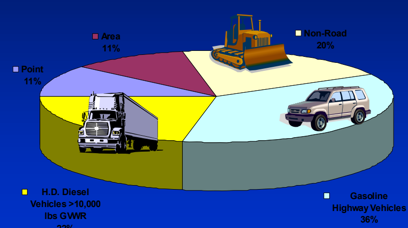



## CRC Report NOx Data




CRC Project No. E-67. Effects of Ethanol and Volatility Parameters on Exhaust Emissions. January 2006

## 2002 Connecticut Emission Inventory
## NOx: 118,704 Tons/Year




## CRC 2006 Study
## Effects of Ethanol and Volatility Parameters on Exhaust Emissions

- Analysis of Non-methane organic gas (NMOG) and 4 air toxics:
  - Formaldehyde
  - Acetaldehyde
  - Benzene
  - 1,3-Butadiene
- Analysis on fuels with High T90 (355° F).

## CRC 2006 Study
## Effects of Ethanol and Volatility Parameters on Exhaust Emissions

- All toxics measured increased emissions when:
  - Fuel properties changed from low to high T
  - Ethanol increased from zero to 10%
  - Increases ranged from 14 to 73%
- Fuel studied does not represent fuel sold in Connecticut.
- Study results cannot predict amplitude of Connecticut toxics exhaust emission increases.

## Conclusions

- Consulting with NESCAUM for further analysis and interpretation of studies.
- More evaluations need to be conducted.
- Listing of resources will be on SIPRAC website.

## Questions ?

**Ellen Pierce, Ph.D.**

**Supervising Environmental Analyst**

**Toxics and Mobile Sources**

**CTDEP Air Planning**

**p: (860) 424-3027 f: (860) 424-4063**

**email:ellen.pierce@po.state.ct.us**

## Public Health Aspects of Ethanol use in Gasoline: Report to CT Legislature

Gary Ginsberg
CT Dept Public Health

## Background

- Public Act 06-53
  - Evaluate health risks assoc w/ethanol-blended gasoline
  - Prior evaluation: NEIWPCC/NESCAUM, 2001
  - Focus of current report
    - Environmental impacts of ethanol-blended gasoline as described in NEIWPCC and Cal (1999)
      - Cal EPA - Joint CARB and EOHHA report
    - Environmental impacts described by CT DEP

## Framework for Assessment

- Gasoline emissions are toxic – must start with a baseline
- Comparison across gasoline blends:
  - 11% MTBE oxyfuel
  - Non-oxygenated fuel
  - 10% ethanol oxyfuel

## Media & Chemicals of Interest

- Air
  - Fugitive emissions from gas tank and pump
    - Ethanol, BTEX, MTBE
  - Exhaust emissions from tailpipe
    - Acetaldehyde, formaldehyde, 1,3-butadiene
- Groundwater / Drinking Water
  - Contaminant plume from spilled gasoline
    - Ethanol, MTBE, BTEX

## Fate and Transport Issues

- Does ethanol modify Reid VP?
  - Alter fugitive emissions?
- Does ethanol increase vapor permeation?
  - CARB/CRC study suggests E10% increases permeation and overall reactivity
- Does ethanol affect exhaust emissions?
- Does ethanol affect breakdown and migration of hydrocarbons in gw?

## Toxic Endpoints

- Ethanol in water – risk to fetus
- BTEX/MTBE in water – cancer and non-cancer
- Acetaldehyde, PAN, formaldehyde in air -
  - acute respiratory effects
- Acetaldehyde, formaldehyde, benzene in air
  – cancer risk
- MTBE, ETX in air – non-cancer effects

## Risk Approach

- Review issues and general trends in releases
  - Qualitative assessment
- Determine whether
  - ethanol subsurface releases likely to be a risk to pregnant women or others
  - increased ambient acetaldehyde/PAN likely to be acute or chronic health risk
    - Consider genetic polymorphism in ALDH-2
  - increased volatile permeation will increase health risks
  - decreases in MTBE/formaldehyde and changes in BTEX counterbalance any increases from ethanol/acet

## Timeline

- Draft DPH Assessment –10/15/06
- Integration with DEP portion / edits
- Complete draft for DEP/DPH approval
- Submit to Legislature – 12-30-06

# STATE OF CONNECTICUT

***DEPARTMENT OF ENVIRONMENTAL PROTECTION***

79 ELM STREET     HARTFORD, CT 06106-5127

PHONE: 860-424-3001

Gina McCarthy
*Commissioner*


November 28, 2006

Senator Bill Finch, Co-Chair
Representative Richard Roy, Co-Chair
Environment Committee
Legislative Office Building
Room 3200
Hartford, Connecticut 06106

Dear Senator Finch and Representative Roy:

I would like to invite you and the ranking members of your committee to attend a stakeholder meeting on Thursday, December 14, 2006, at 9 A.M., in the Phoenix Auditorium at 79 Elm Street, Hartford, Connecticut. This meeting is to gather comments on the report being prepared by the Connecticut Department of Environmental Protection (DEP) and the Department of Public Health (DPH) on the use of ethanol in gasoline, as required by Section Six of Public Act No. 06-053. This Public Act requires the Connecticut Department of Environmental Protection (DEP) and the Department of Public Health (DPH) to study the effects of using ethanol in gasoline from both an air quality perspective and a public health perspective. This invitation is in response to your August 31, 2006 inquiry regarding the status of the report, to which I replied on September 29, 2006, assuring you that you would be apprised of our continued progress.

This stakeholder meeting will be part of the State Implementation Plan Research Advisory Council (SIPRAC) monthly meeting at DEP headquarters. On September 14, 2006, DEP held an initial stakeholder meeting during which DEP and DPH presented overviews of the framework for their work on this study. The presentations, as well as a list of references upon which the study was being conducted, were posted on the DEP website at
http://www.dep.state.ct.us/air2/siprac/2006/sip06.htm#sept.

DEP plans to finalize the report following this stakeholder meeting and to submit the final report to the General Assembly by December 29, 2006. If you have any questions please do not hesitate to contact Tom Tyler, Legislative Liaison, at (860) 424-3001.

Yours truly,

Gina McCarthy
Commissioner

GM/emp

cc: John McKinney
Clark Chapin
Gary Ginsberg, DPH
Tom Tyler, DEP

# SIPRAC Presentations
# December 14, 2006

## Public Act 06-53 (Section 6) Ethanol Report

Ellen Pierce, Ph.D.
Air Planning
SIPRAC
December 14, 2006

## Ethanol Report to General Assembly

- An Act Concerning Protection of Public Water Supply Resources: Public Act 06-53 Section 6.
- Due on December 31, 2006.
- DEP to study effect on Connecticut's air quality of using ethanol in gasoline.
  - Effect on emissions and attainment of NAAQS
- DPH to study health implications.

## Ethanol Study Report Requirements

- Analysis of NESCAUM/NEIWPCC reports.
- Analysis of whether to continue use.
- Effect on air quality.
- Update on other states' actions.
- Recommendations for alternative or supplemental emission reduction opportunities.
- Must be completed within available resources, no funding appropriated.

## Why We Have Ethanol in Connecticut

- Originally MTBE used as octane enhancer.
- 1992: Served as a CO control measure.
- 1995: Suppliers added MTBE to meet the 2% RFG oxygenate requirement.
- Concerns with groundwater contamination.
- January 1, 2004 statutory ban prohibiting sale of MTBE as a gasoline additive: Public Act 03-122.
- Ethanol was only viable option to meet oxygenate requirement.

## Simplified Photochemistry of Ozone Formation


## Ethanol in Connecticut Gasoline

- 5.7% ethanol by volume complies with 2.0% oxygen
- Refiners choose to blend ethanol at 10% by volume (3.5% oxygen by weight).
  - Federal Tax Incentives of $0.51/gallon of ethanol
- RFG used in CT and NY, is currently blended with 10% ethanol.
- CT consumption of gasoline 1.65 billion gallons for 2005

## NESCAUM and NEIWPCC 2001 Report

- Continue to monitor ambient air for ozone precursors.
- Evaluate monitoring data to assess any changes in air quality attributable to this use of ethanol.
- Recommendation to phase out use of MTBE.
- Recommendation to waive the RFG oxygenate requirement.

## Energy Policy Act of 2005

- Signed into law August 8, 2005.
- Eliminated RFG 2.0% oxygen by weight requirement.
  - Effective May 6, 2006
- Eliminated oxygenate requirement waiver process.
- Introduction of Renewable Fuels Standard (RFS).
  - Designed to reduce dependence on foreign oil
  - Limits ability of states to adopt or initiate boutique fuels

## Renewable Fuels Standard (RFS)

- 2.78% of fuel sold in 2006 must be from renewable sources (4.0 billion gallons).
- EPA's proposal to increase to 3.71% for 2007 (4.7 billion gallons).
  - November 11: comment period closed
  - Final rule expected in February
- By 2012, RFS increases to 7.5 billion gallons.

## Boutique Fuel Issue

- Banning ethanol use in RFG would create a new boutique fuel.
- Future strategies need to consider the issue of creating a boutique fuel.
- Ultimately, there are hurdles under EPAct that will be difficult to overcome.

## Ethanol Actions by Other States

- Regulatory
  - **California** regulations limit ethanol to 5.7% by volume with exemption provided for fine particulate matter control
- Non-Regulatory
  - Incentives
  - http://www.eere.energy.gov/cleancities/ccn/progs/story.php/WHATS_NEW/635/0/A

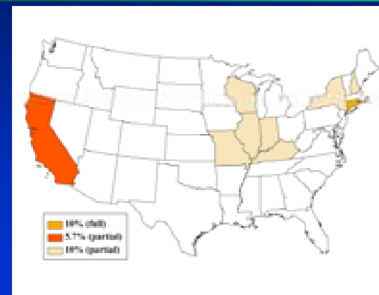
## 2006 US Gasoline Standards

ExxonMobil, May 2006

## States with MTBE Bans


ACE STATUS 2006: State by State Ethanol Handbook

## RFG States with MTBE Bans Volume Percent of EtOH Blends



## Existing Studies for Consideration

- Efforts focused on existing studies
- Several studies by CARB and Coordinating Research Council (CRC)
- Emissions
  - Evaporation: Venting/leakage and permeation
  - Exhaust
- Permeation is diffusion of fuel through rubber and plastic components of fuel and fuel vapor systems.

## Fuel Permeation


## Preliminary Findings

- Quantification of specific changes not possible based upon available data.
  - Published reports based upon California fuel blends and temperature profiles
  - Fuels utilized to test air toxics are not representative of fuel parameters sold in Connecticut
  - Uncertainty in extrapolating to Connecticut.

## Preliminary Findings (cont.)

- Cal LEV II Program
  - Implementation and fleet turnover will achieve significant emission reductions and provide for evaporative controls.
  - PZEV standards will achieve zero evaporative emission
  - Reduction of exhaust emissions
- Ongoing CA research suggests
  - Permeation dependent on fuel blend, temp, vehicle design and year
  - Exhaust emission levels are sensitive to fuel parameters in newer cars (TIER I and newer) .

## Preliminary Findings (cont.)

- EPAct eliminated the need to request a waiver from the oxygenate requirement in RFG.
- EPAct includes restrictions and hurdles for states to adopt new “boutique fuels”.
- Ethanol in gasoline does not result in the emission of new air toxics.
- Results from new studies will be factored into attainment planning.

## Preliminary Findings (cont.)

- **Benefits**
  - Use of ethanol is integral to reducing the state’s dependence on fossil fuels.
  - Greenhouse gas reductions from displacement of 165 million gallons of gasoline.

## Draft Report

**Available at:**

**http://www.dep.state.ct.us/air2/siprac/2006/sip06.htm#sept**

## Comments

**by**

**Monday, December 18**

**Patrice Kelly**

**Air Planning**

**p: (860) 424-3027 f: (860) 424-4063**

**email:patrice.kelly@po.state.ct.us**

## Public Health Aspects of Ethanol use in Gasoline: Report to CT Legislature

Brian Toal and Gary Ginsberg

CT Dept Public Health

860-509-7742

## Background on DPH Evaluation

- Builds on Prior Evaluation:
  - NEIWPCC/NESCAUM, 2001 report
    - – main focus was ethanol as gw contaminant
- Focus of current DPH analysis – Does EtOH ……
  - 1. Cause the release of unique toxic chemicals into
  - the atmosphere or groundwater?
  - 2. Increase or decrease the release of existing toxic chemicals
  - into these media; and
  - 3. Increase or decrease public health risks associated with the
  - use of gasoline in Connecticut.

## Framework for Assessment

- Gasoline emissions are toxic – must start with a baseline
- Comparison across gasoline blends:
  - 11% MTBE oxyfuel
  - Non-oxygenated fuel
  - 10% ethanol oxyfuel

## Ethanol Impacts on Evaporative Emissions: *Fugitives*

- Fugitive emissions from gas tank and fuel lines
  - Ethanol increases RVP
  - Would get more release of VOCs but:
    - RVP cap (7psi)
      - » prevents EtOH to increase fuel RVP above acceptable limits

## Ethanol Impacts on Evaporative Emissions: *Permeation*

- Permeation Emissions
  - Ethanol ↑s permeation of VOCs across hoses, seals
  - CRC studies (2004, 2006) - California conditions
    - modest increase – up to 3 g/d
  - Mitigating factors
    - Ethanol permeate 30% lower $O_3$ reactivity
    - Permeation currently a relatively small source of evaporative emissions (26%?)
    - As new cars come on line, permeation % may increase, but other fuel changes may also occur
    - Ethanol displaces more toxic constituents (BTEX)
  - Ongoing and new studies need to be evaluated

## Ethanol Impacts on Evaporative Emissions: *Continued*

- Earlier modeling studies by CARB (1999)
  - Ethanol in gasoline, no major effect on BTEX
    - Increased evap emissions balanced by replacement of other VOCs in the fuel
- Ethanol levels in atmosphere well below PH concern
  - Daily inhaled dose well below EtOH in glass of OJ
  - Actually monitoring data from high EtOH use areas (Brazil) support this

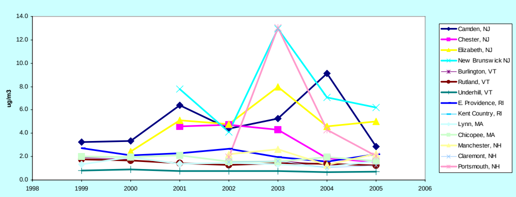
## Ethanol Impacts on Exhaust Emissions: ***Aldehydes, PAN, Butadiene, NOx***

- Theoretical increase in:
  - Acetaldehyde – irritant gas from EtOH oxidation
  - Peroxyacetylnitrile (PAN) – irritant, byproduct of EtOH
  - NOx – irritant and ozone precursor, ↑ed from extra O
- Theoretical decrease in:
  - Formaldehyde – more toxic than acet; formed from MTBE
  - 1,3-Butadiene – carcinogen; ↓ due to more complete combustion

## Possible Changes in Acetaldehyde

- CRC exhaust study suggest EtOH-10 doubles acet emission
- Modeling: thats only 12% ↑ in airborne acet
  - Many background acet sources
  - Acet short half-life in atmosphere
  - Monitoring data – Denver, Brazil support this
    - Data from E Htford 2003 vs 2005 support this
- Airborne levels below PH concern
  - Even for Asian descent – ALDH-2 polymorphism

**Figure 5:**
**Trend in Acetaldehyde Concentrations 1999-2005**
*prepared by NESCAUM*




## Possible Changes in NOx

- CRC: possible NOx ↑ from EtOH-10
  - Variable finding, dependent upon fuel blend
- East Hartford Monitoring
  - Summer 2003 vs Summer 2005
  - 27% decrease in NOx – probably related to other reduction initiatives

## Changes in Other Exhaust Emissions: 1,3-Butadiene, Formaldehyde, PAN

While theoretically possible, current evidence suggest the increases or decreases would be minor and difficult to document

## Potential Change in Ozone

- Theoretical increase due to increases in:
  - VOC permeation
  - NOx exhaust emission
- VOC concern mitigated somewhat by
  - Lower reactivity of permeate emission
  - Major driver for $O_3$ is availability of NOx
- NOx concern mitigated somewhat by
  - Studies don't clearly show an E-10 ↑ relevant to CT

## Ethanol in Groundwater

- Risk from Ethanol less than for MTBE
  - Breaks down faster in gw
  - Drinking water limit would be several times higher than for MTBE
  - Unlikely that EtOH is an impt gw pollutant
- Potential for Co-solvency Transport
  - High EtOH in gw can enhance plume transport
  - This is unlikely with E-10 fuel

## DPH Summary Evaluation & Preliminary Findings

- A variety of changes in fuel-related emissions possible when using E-10
- Data directly relevant to CT not available
- Implications from Cal: changes relatively minor with no obvious impact on PH
- Does not appear that novel pollutants formed
- Groundwater not a significant concern
- More studies and updating of analysis needed

NESCAUM

# Evaporative Emission Impacts of Ethanol in Gasoline

Matt Solomon
NESCAUM
**SIPRAC, Connecticut DEP**
**December 14, 2006**

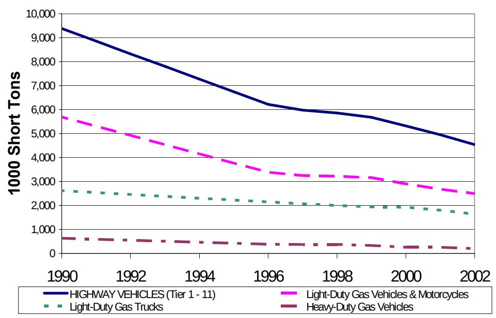
NESCAUM

## Overview

- **Background**
  - Contribution of evaporative emissions to total VOC
  - Evaporative emission trends
- **Evaporative Modes and Mechanisms**
- **CRC Studies**
  - Permeation: E-65 and E-65-3
  - Evaporative mechanisms: E-77
- **Inventory Impacts**
- **Conclusions**

NESCAUM

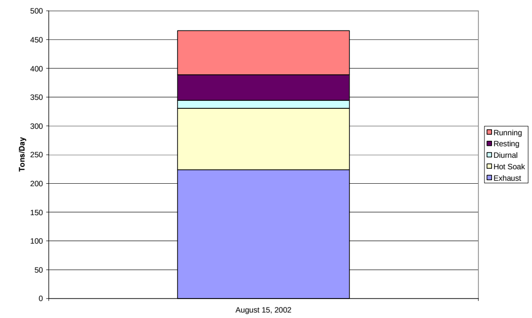
## US Annual VOC Emissions




Source: US EPA, NEI Air Pollutant Emission Trends Data, http://www.epa.gov/ttn/chief/trends/index.html#tables, accessed 11/27/06.

NESCAUM

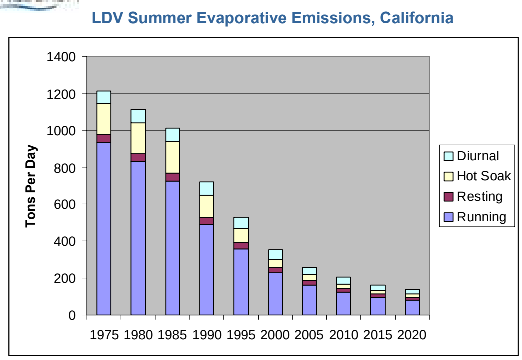
## Mobile Source TOG Emissions, NESCAUM States




Source: SMOKE Model, based on MOBILE6 Emission Factors.

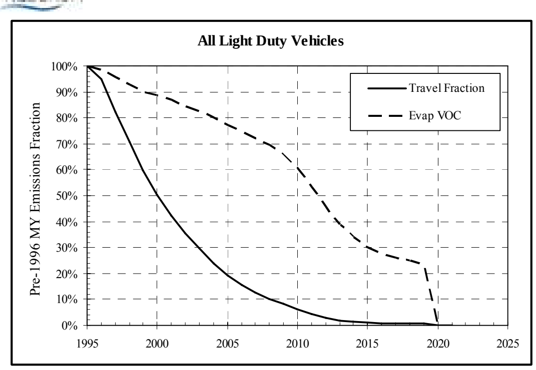
NESCAUM

## LDV Summer Evaporative Emissions, California




Source: California EPA, 2006 Almanac CEFS Emissions by Summary Category Reports, http://www.arb.ca.gov/app/emsinv/fcemssumcat2006.php, accessed 11/27/06.

NESCAUM



NESCAUM

## Vehicle Evaporative Emissions: Modes vs. Mechanisms

| Emission Mechanisms | Operation Modes |
|---|---|
| • Leaks (liquid & vapor)<br>• Canister losses ("Venting")<br>• Permeation | • Diurnal<br>– Breathing (Temp Rise)<br>– Resting (Temp falling or stable)<br>• Hot soak<br>• Running losses<br>• Refueling |

***Each mechanism may occur during any mode.***

Source: Harold Haskew, **Ethanol's Effects on Automotive Permeation**, SCAQMD Ethanol Forum & Technical Roundtable, June 15, 2006

NESCAUM

## Evaporative Emission Mechanisms

- **Leaks and venting**
  - **Functions of:**
    - **Fuel volatility (RVP)**
    - **Fuel system integrity**
    - **Canister capacity and efficiency**
  - ***NO ETHANOL EFFECT (with constant RVP)***
- **Permeation**
  - **Migration of fuel molecules through fuel system components**
  - **Not RVP-dependent**
  - **Not captured in Complex model**
  - **Strongly influenced by presence of ethanol in low concentrations (6% and 10%)**
  - **Temperature dependent: rate doubles with each 10ºC.**

NESCAUM

## Recent CRC Permeation Studies

**CRC E-65 (2004)**

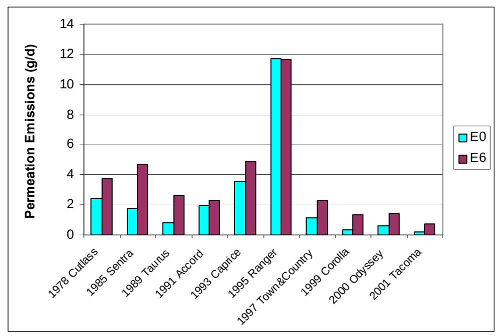
- **10 Vehicles, MY 1978 – 2001**
- **3 Fuels: MtBE, E6, Non-oxygenated**
- **Average permeation rate for all vehicles increased 65% with E6 compared to MtBE blend**
- **Average permeation rates on post-1996 vehicles increased 157% with E6 compared to E0**

**CRC E-65-3 (2006 – preliminary results only)**

- **5 Vehicles: 2 'enhanced', LEV-2, PZEV, Flex-Fuel**
- **5 Fuels: E0, E6, E6-Hi, E10, E85**
- **Average 200% increase with E10**
- **Permeation *decreased* by 50% with E85 compared to E0**
- **Average specific reactivities were ~30% lower per gram of permeate with E6 and E10 compared to E0**
- **Ethanol appears to promote permeation of non-ethanol species**

NESCAUM

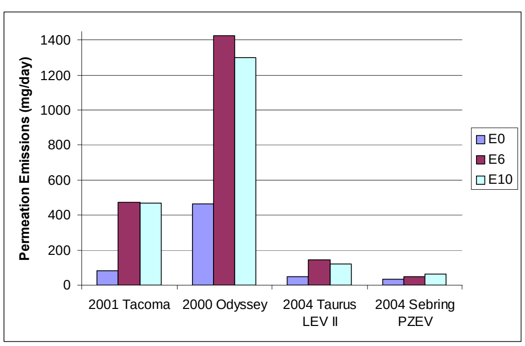
## CRC E-65 Results




Source: Coordinating Research Council, ***Permeation From Automotive Systems*, Final Report, CRC Project # E-65, September 2006.**

NESCAUM

## CRC E-65-3 Results




Source: Coordinating Research Council, ***Fuel Permeation From Automotive Systems: E0, E6, E10 and E85*, Interim Report, CRC Project # E-65-3, August 2006.**

NESCAUM

## CARB's Estimated Impacts (Draft): South Coast Air Basin

- 17.4 tpd increase for typical ozone day (84ºF peak)
- 20.5 tpd increase for high-ozone day (98ºF peak)
- Statewide: 45 tpd from cars, 10tpd from small engines
- Based on EMFAC modeling assumptions:
  - 6% of running losses, 13% of hot soak, 66% of diurnal emissions
  - 26% of total evaporative emissions
- Total impact is *highly dependent* on permeation fraction!

Source: CARB, A Summary of the Staff's Assessment Regarding the Effect of Ethanol in California Gasoline on Emissions, Draft Report, February 2005.

## What is the contribution of permeation effects to total evaporative emissions?

- No data available (E77 should provide some insight)
- Historically probably very low
  - Carburetors were a major source of evaporative emissions
  - Basic controls (pre-1996) much less effective at capturing venting emissions
- Likely increasing as venting losses are better controlled

## What is the contribution of permeation effects to total evaporative emissions?

"…now that carburetors are no longer in production, fuel volatility is under control, and the enhanced evaporative emissions regulations have forced the vehicle to actively and aggressively purge the canister during driving, ***the only mechanism of significance is the permeation***." (emphasis added)

-Harold Haskew, "A New Approach to Modeling On-Road Vehicle Evaporative Emissions"

Source: Harold Haskew, **"A New Approach to Modeling On-Road Vehicle Evaporative Emissions"**, June 2005

## CRC E-77

- First step toward characterizing evaporative emissions for enhanced-evap and later vehicles
- Pilot study to validate test method
- Sponsors include ARB, EPA
- Results expected early 2007.

## Conclusions

- E6 and E10 shown to significantly increase permeation from some vehicles
  - Increase is less pronounced with PZEV systems
- Permeation greatest at high temperatures
- VOC increase partially offset by lower ozone-forming potential of permeate
- Fleet mix and meteorological conditions are major factors
- Insufficient data to predict impact on emissions inventory
- Increase in permeation fraction may cause upward revision of ethanol evaporative impact estimates
- TIER-2 and LEV-2 vehicles certified with ethanol (durability testing), so permeation increase should not be long-term issue
- May remain issue for nonroad equipment

## Questions?

**From: judge.robert@epamail.epa.gov**
**Sent: Friday, December 15, 2006 3:27 PM**

**To: Kelly, Patrice**
**Cc: arnold.anne@epamail.epa.gov**
**Subject: RE: Revised Agenda for SIPRAC, December 14, 2006**

**Hi Patrice---**

**Excellent and very thorough report. 2 questions/ comments:**

**On Page 4- you might want to be clear about "exhaust emissions are greatly reduced in LEVs" The NOx would be about the same with tier 2- and the VOCs reductions would be greater- but including a number would be useful-- which will vary based on the model year.**

**On Page 5- you observe that E-10 will increase NOx. You might want to talk about "how much" of a NOx increase and whether there are other advantages relative to using E-10- other pollutants benefits(CO/ VOC), and their effect on ground level ozone...**

**Thanks, Bob**

TO: Tracy Babbidge, DEP
FROM: Steven Guveyan, CT Petroleum Council/ API
RE: DEP Draft Ethanol Report

Thank you for sharing the preliminary draft with us. It is a large body of work that is being completed in a short amount of time. There are a number of very good points made in the paper, as well as some points made which I was unaware of. Several of us at API reviewed the Ethanol Draft report; our comments are outlined below.

The report focuses almost exclusively on E-10, and makes little mention of E-85. It is unclear to us whether the report is supposed to focus on E-10 and E-85, or just the former. The report lists and highlights some E-85-related material in the Reference Material and summary literature reviews provided in the Appendix, but none of this is discussed in the main body of the report. We recommend some more discussion of E-85 be added, especially since we know the legislature in CT will be considering it (or at least include some explanation of why E-85 isn't being addressed).

Is the report supposed to have a near-term focus, or should it also look "down the road"? It appears to be strictly near-term, as there is virtually no discussion of the prospects for (or implications of) cellulosic ethanol (except for the inclusion of some reference material on the latter in the Appendix). Perhaps the Executive Summary and/or introduction should clearly state that cellulosic ethanol is not being addressed in this document.

The text in the first graph on air quality impacts: tailpipe emissions (p.12) related to the discussion of the CRC Project E-67 is confusing and not entirely correct.

On p.14, in the discussion of acetaldehyde emissions, the report makes some confusing and incorrect linkages between the timing of the CRC Project R-87 study and a CAR/CalEPA study.

On p.16, the discussion regarding the effect of ethanol on greenhouse gas emissions is misleading and potentially wrong, and also inadequately referenced---the API comments on this portion of the report were harsh. The report says that a gallon of ethanol provides 20% fewer GHG emissions than a gallon of gasoline, but provides no source or frame of reference for this figure. Is it life-cycle based? It should be. If so, the estimate is high relative to recent reports from the Univ. of Cal. at Berkeley and the Univ. of Minnesota published in peer-reviewed literature that pegs the reduction at 12-13%.

On p. 18-19 in the Table 3 Summary of environmental and health risks associated with ethanol, the report says---with respect to GHG emissions---"significant reductions" in potential air and water quality impacts and "significant" potential impact on human health. However, there isn't any evidence we can find in the report to support these claims.

Now that CT has been using ethanol for almost 3 years, DEP may want to evaluate in substantive fashion whether the use of ethanol here has (or has not) been a good thing.

The discussion of groundwater quality impacts from ethanol fuel releases is quite brief (2 graphs), and while it hits the high points, it does not address some of the other potential issues that are raised in Appendix 7. Stated differently, the paper shortchanges groundwater issues, compared to air issues. The report does not discuss other related issues such as how the use of ethanol would affect emissions from increased tanker truck activity around terminals, etc.

The discussion on health impacts of direct exposure to ethanol in the air (p. 9) only considers ambient ethanol concentrations, and does not discuss any potential exposures to consumers at the pump, in vehicles, or houses with attached garages. Not certain those exposures would be significant, but they should be briefly addressed.

Procedurally, there should be a "Table of Contents". Also, the report includes items in the "Preliminary Findings" (such as the need for continued evaluation of emission reductions in the off-road sector) which are not even mentioned in the main report. Finally, it would be helpful if the material in the appendices were better organized. For example, the Appendix 2 literature review by NESCAUM is simply a string of brief summaries of documents. It would be helpful if the summaries were organized by some broad topic areas (i.e. health-related studies, groundwater, air quality and emissions, E-10 vs. E-85, corn-based ethanol vs. cellulosic, etc.).

Please let me know if you need additional info from us, or specific language, especially in the GHG-related section. If needed, we can put together a conference call with the API reviewers, too. Again, many thanks for sharing the preliminary draft with us.