HEALTH, ENVIRONMENTAL, AND ECONOMIC IMPACTS OF ADDING ETHANOL TO GASOLINE IN THE NORTHEAST STATES

NEIWPCC
New England Interstate Water Pollution Control Commission

NESCAUM
Northeast States for Coordinated Air Use Management

VOLUME 1

SUMMARY AND RECOMMENDATIONS

JULY 2001

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SUMMARY AND RECOMMENDATIONS

OVERVIEW

The federal reformulated gasoline (RFG) program was designed to reduce emissions of motor vehicle pollutants. To comply with the RFG program, gasoline must achieve a set of emission performance standards and meet a minimum oxygen content requirement. Approximately three-quarters of all gasoline currently sold in the Northeast market is RFG. By and large, refiners have opted to comply with the oxygen requirement by selling RFG containing methyl *tertiary*-butyl ether (M*t*BE) at 11 percent by volume, which translates to more than one billion gallons of M*t*BE sold annually in the Northeast. While the use of M*t*BE in gasoline has increased dramatically since 1995 due to the minimum oxygen requirement in the RFG program, this additive has been used as an octane enhancer in some gasoline for many years.

The RFG program has provided substantial reductions in the emissions of smog-forming pollutants, benzene and other hazardous air pollutants from motor vehicles. However, substantial evidence exists showing that the unique chemical and physical properties of M*t*BE pose an unacceptable risk to our region's potable water supply. In response to this threat, the Northeast states are seeking ways to dramatically reduce or eliminate M*t*BE from the region's gasoline supply. The challenge facing policymakers is to maintain the air quality benefits of the RFG program while reducing the threat that M*t*BE poses to the region's critical water resources.

M*t*BE and ethanol are the only two oxygenates currently produced in quantities sufficient to meet the demand created by the RFG program. Therefore, under current federal law, eliminating M*t*BE represents a de facto mandate for ethanol in RFG. Because M*t*BE and ethanol are valuable high-octane components, the use of ethanol in gasoline is likely to increase dramatically as M*t*BE is phased-out in the Northeast, even without the oxygen requirement.

To better understand the consequences of potentially introducing hundreds of millions of gallons of ethanol into the region's gasoline pool, the New England Governors' Conference Committee on the Environment asked the New England Interstate Water Pollution Control Commission (NEIWPCC) and the Northeast States for Coordinated Air Use Management (NESCAUM) to assess the potential public health, environmental, regulatory and economic impacts associated with such a shift. Of primary concern are air quality impacts, the potential impact of ethanol on water resources, infrastructure requirements, and the economic costs of a shift from M*t*BE to ethanol. The State Environmental Commissioners further asked NEIWPCC and NESCAUM to develop recommendations to alleviate or minimize any potential adverse effects associated with a significant increase in fuel ethanol use. In response to growing interest, this study also resummarizes available information on the potential for developing biomass ethanol production capacity in the Northeast. This paper highlights key findings of the NEIWPCC and NESCAUM analyses and provides research and policy recommendations for consideration by the Northeast states. The analyses behind these findings and recommendations are detailed in separate technical papers produced by NEIWPCC and NESCAUM.

This document is the latest in a series of reports issued over the last several years by the Northeast states on the topic of RFG, M*t*BE and ethanol. Consequently, several of the conclusions and policy recommendations contained herein are derived from and supported by these earlier analyses. Broad policy recommendations—including the need for legislative and regulatory action to eliminate M*t*BE, lift the oxygen mandate, prevent backsliding on air quality benefits, and ensure that a federal ethanol strategy is national in scope—were previously endorsed by the Northeast states. Similarly, the decision by some member states to ban M*t*BE was made prior to this report. Therefore, policy recommendations that include a continued significant role for M*t*BE are not considered here. Readers are encouraged to consult previous NESCAUM reports on this topic.[1]

This evaluation is intended to provide our member states with timely policy guidance. In order to conduct a detailed technical assessment of the environmental and economic consequences of increased ethanol use in our region, it would be necessary to conduct field experiments to document the fate and transport of ethanol in the Northeast environment and detailed economic analyses to predict the cost and fuel supply impacts of various fuel scenarios. These activities are beyond the scope of the efforts conducted to date. NEIWPCC and NESCAUM recommend such studies be undertaken to refine our understanding of the issues at hand. However, the information summarized in the attached technical papers provides compelling justification for the technical findings and policy recommendations that follow. Should the policy landscape change as a result of federal or state actions that would significantly alter gasoline formulations or diminish the likely role of ethanol in favor of other fuel constituents, further analysis may be needed to properly inform the region's policymakers regarding the potential consequences of such action.

SUMMARY OF RECOMMENDATIONS

Based on the findings of this study and previous analyses conducted by the Northeast states, NEIWPCC and NESCAUM offer the following research and policy recommendations (see pages 20-23 for full set of recommendations):

1. Legislative and regulatory initiatives to remove M*t*BE from gasoline;

- ▲ Congressional action to lift the oxygen mandate for RFG
- ▲ pending effective Congressional action, USEPA should grant state requests to waive the RFG program's oxygen requirements
- ▲ clarification of state and federal authority to regulate gasoline additives
- ▲ regionally coordinated phase-out of M*t*BE

2. Legislative and regulatory action to ensure the appropriate use of ethanol;

- ▲ any federal program requiring ethanol in gasoline should allow refiners and suppliers to meet their sales quotas nationally, on an annual average basis, and provide incentives for ethanol made from cellulosic biomass

3. U.S. Environmental Protection Agency (USEPA) initiatives to prevent adverse air quality impacts;

- ▲ establish air toxic performance standards based on actual reductions achieved by RFG (i.e., no "backsliding")
- ▲ repeal the one-pound RVP waiver for ethanol-blended conventional gasoline

4. Refinery modeling to predict future fuel formulations, fuel supply impacts and the average cost impacts associated with diminished M*t*BE use in the Northeast, including the cost to remedy potential adverse air quality impacts related to ethanol use;

5. Controlled field studies to understand the true extent of the environmental fate and transport of ethanol and ethanol-blended gasoline in the Northeast;

6. Efforts to evaluate, upgrade and improve, where necessary, the region's gasoline storage and transport system to accommodate ethanol and ethanol blends;

7. A regionally consistent and coordinated air and water quality monitoring network for ethanol;
   - ▲ Northeast states should develop and employ standardized analytical methods for measuring ethanol in environmental water samples, including acceptable detection limits
   - ▲ states should design and deploy an air and water quality monitoring network that will, at a minimum, measure ambient ethanol concentrations at likely worst case locations

8. Airshed and human exposure modeling to evaluate the impacts from the potential change in ambient concentrations of ethanol, combustion by-products (acetaldehyde and formaldehyde) and other hazardous air pollutants associated with a substitution of ethanol for M*t*BE;

9. Development of a model oxygen waiver request and technical support document for states interested in pursuing a waiver of the RFG program's oxygen mandate; and

10. Further exploration of opportunities to develop an indigenous industry to produce fuel ethanol from cellulosic biomass in the Northeast.

SUMMARY OF KEY FINDINGS

HEALTH EFFECTS

- ▲ Gasoline is a complex mixture containing hundreds of compounds, many of which are known or suspected human carcinogens and/or contribute to ozone and fine particulate matter formation, as well as water pollution.

- ▲ Exposure to gasoline-related toxins in the air and water presents potential public health risks.

- ▲ Given current information, ethanol appears to be one of the least toxic of the major components of gasoline when considering common toxicological endpoints, such as carcinogenicity and central nervous system depression.

- ▲ Preliminary analyses indicate that direct exposure to fuel ethanol in the air and in contaminated drinking water is not expected to pose public health risks.

- ▲ The potential for other adverse impacts, including developmental effects, associated with large-scale exposure to low levels of ethanol is uncertain.

- ▲ Additional analyses to estimate ambient exposure to ethanol and its atmospheric breakdown products, including highly toxic constituents such as acetaldehyde and peroxyacetylnitrates (PAN) are needed to assess the potential public health impacts of increased ethanol use in Northeast.

- ▲ Studies have found strong correlations between the introduction of cleaner-burning gasoline and reduced concentrations of ozone, ozone precursors and air toxics in the ambient air. The specific contribution of oxygenates in achieving these benefits is difficult to quantify at this time.
- ▲ Air toxic and ozone precursor emissions could increase from both RFG and conventional gasoline if ethanol substantially replaces M*t*BE in the region's gasoline supply. However, these adverse impacts can be minimized with appropriate legislative and regulatory actions at the state and federal level including adoption of anti-backsliding provisions, repeal of the oxygen mandate and the elimination of volatility waivers for conventional gasoline blended with ethanol.
- ▲ While the air quality benefits of RFG could diminish somewhat if ethanol replaces M*t*BE, under any scenario, the program will continue to provide important public health benefits compared to conventional gasoline.
- ▲ Ethanol-blends provide some air quality benefits compared to non-oxygenated blends including lower rates of carbon monoxide and particulate emissions, as well as greenhouse gas benefits.
- ▲ With ethanol, the carbon monoxide benefits will partially offset the adverse ozone impacts associated with increased NOx and VOC emissions.
- ▲ Low-level ethanol contamination of groundwater (i.e., less than 400 µg/L, a draft Water Comparison Value derived in this report) is not expected to substantially alter blood alcohol concentrations or produce a significant health risk. The potential health risks in sensitive subjects such as pregnant women or those who may have aldehyde dehydrogenase deficiency were considered in reaching this conclusion.
- ▲ Higher concentrations of ethanol in water 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 10 mg/L (ppm). Thus, the hazard potential of ethanol (production of irreversible fetal effects) is mitigated by the fact that relatively high environmental concentrations would be needed to reach a level of public health concern and by the fact that such concentrations are unlikely given the physical and chemical properties of ethanol.
- ▲ The hazard potential for ethanol is greater than that for M*t*BE in terms of the types of irreversible damage possible from repeated high-level exposures. In spite of this greater hazard potential, the draft Water Comparison Value for ethanol in drinking water appears to be at least as high, if not higher, than M*t*BE.

ENVIRONMENTAL IMPACTS

- ▲ Gasoline spilled and leaked into the environment is a major source of water pollution. At elevated levels, gasoline and its constituents can adversely affect the quality of drinking water, pose a threat to public health and threaten aquatic life.
- ▲ Because it biodegrades quickly in the environment, ethanol poses significantly less risk to water resources than M*t*BE. However, the following environmental transport properties of ethanol are cause for some concern: (1) at high concentrations, ethanol can make other gasoline constituents more soluble in groundwater; (2) when present in a gasoline spill, ethanol can delay the degradation of other, more toxic components in gasoline; and (3) 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 M*t*BE in small-volume gasoline spill scenarios, the relative impacts of large-volume gasoline spills are harder to generalize due to the uncertainties in quantifying the effects of ethanol on BTEX plume length, the concentration of terminal electron acceptors, and secondary effects on groundwater quality, such as increased levels of dissolved iron.
- Under acute exposure conditions, ethanol is 3.7 times less toxic to aquatic life than M*t*BE. Over longer periods of exposure, ethanol is thought to be similar, if somewhat less toxic, than M*t*BE in terms of impacts on aquatic life. However, ethanol is not expected to persist for long periods in the environment.
- 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 M*t*BE in soil should work in remediating spills of neat ethanol and ethanol-blends. However, until these technologies are field tested, it is difficult to determine the cost and relative efficacy of the various 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.
- Since ethanol is highly biodegradable, biological treatment technologies offer significant promise, although in-situ bioremediation technologies would have to be scaled-up relative to those currently used.
- It is premature to speculate on how the presence of ethanol blends will affect soil and groundwater remediation costs since several significant factors regarding the fate and transport of ethanol in the environment are unknown.

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 to establish.
- Infrastructure needs may present siting difficulties and regulatory issues. For example, space constraints may prove to be an important obstacle in siting new tanks at petroleum storage and distribution facilities.
- To accommodate the amount of ethanol that would be needed to meet RFG demand, barge, rail and truck facilities would need to be added or expanded at bulk terminal and port facilities in the region.
- The materials used to fabricate UST/AST systems have evolved over time to accommodate the storage of ethanol and ethanol-blend fuels. 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, submersible pumps, fuel dispensers, piping, hoses, nozzles and swivels.

ECONOMIC IMPACTS

- The economic consequences of replacing M*t*BE in gasoline with ethanol and the resulting efforts to weaken environmental standards to reduce these costs are likely to represent the greatest impact in the Northeast.
- Fuel reformulation and infrastructure needs are predicted to increase the cost of RFG in the region if ethanol replaces M*t*BE.
- Removing M*t*BE from the region's gasoline pool is likely to increase fuel costs and may create near-term volume supply shortfalls, whether the oxygen mandate is retained or not. However, costs increases and potential supply shortfalls are likely to be more severe with the mandate than without the mandate.
- Existing information suggests that producing RFG with ethanol will increase per gallon costs by 3 - 11 cents in the near-term. These cost estimates are likely to be conservative because they do not reflect the combined demand for ethanol in both the Northeast and California and they do not reflect the maintenance of full air quality benefits provided by the RFG program. Incremental cost increases are expected to decline with a longer M*t*BE phase-out period.
- A one-cent per-gallon increase in the cost of RFG will result in a $120 million per year expense for Northeast consumers. If the average cost of all gasoline (both RFG and conventional) in the Northeast increases by 7 cents per gallon, total annual costs to the region would be on the order of $1 billion. Since most RFG and ethanol is produced outside the Northeast, increased gasoline costs will result in a substantial outflow of resources from the regional economy.
- Costs could be higher than those predicted if the goal is to hold public health harmless with regard to air toxics and ozone emissions.
- Increased demand and constrained supplies are likely to result in higher near-term costs for ethanol and other valuable blendstocks, such as alkylates, in the early years of a national shift away from M*t*BE.
- There may be significant adverse impacts on the state highway funds, due to the structure of the federal subsidy program to encourage fuel ethanol use.
- The development of cellulosic biomass ethanol production capability in the Northeast presents a potential economic opportunity that could reduce the long-term cost and increase the economic and environmental benefits of fuel ethanol use in our region.

BACKGROUND

The New York City Metropolitan area, Greater Connecticut (Hartford and environs) and the Philadelphia CMSA are required to sell federal RFG; other parts of the region have voluntarily opted into this program through January 1, 2004. The RFG program provides important public health benefits in the northeast states by reducing exhaust and evaporative emissions of smog precursors and other hazardous air pollutants (HAPs) from motor vehicles. It is an important component of the overall strategy that has succeeded in reducing the number of violations of the federal ozone standard in the region and will be needed in the continuing effort to control smog. Motor vehicles and fuels are a primary source of public health risks associated with exposure to hazardous air pollutants (HAPs) and RFG is a proven strategy for reducing emissions of these toxic compounds.

As mandated in the Clean Air Act (CAA), RFG must contain a minimum of 2 percent oxygen by weight; this is equivalent to 11 percent M*t*BE by volume or 5.7 percent ethanol by volume. M*t*BE has been the primary oxygenate used by refiners supplying gasoline to the Northeast because it has clean burning characteristics, provides a good source of octane and is relatively inexpensive. Moreover, unlike ethanol, M*t*BE can be blended into gasoline at the refinery and transported through existing pipelines. However, the northeast states, California and others have concluded that M*t*BE poses an unacceptable threat to water resources because of its high mobility in groundwater and its resistance to biodegradation. Since the introduction of RFG in 1995, M*t*BE has been detected in an increasing number of private and public water supplies. Due to taste and odor characteristics that affect drinkability and concern about possible acute and chronic health effects, a broad consensus has emerged that the use of M*t*BE in gasoline should be curtailed.

Unless Congress eliminates the oxygen mandate in the CAA or the USEPA grants oxygen waivers to individual states, RFG must contain 2 percent oxygen by weight. Since several states in the Northeast have decided to ban M*t*BE and most others support a reduction in its use, an alternative oxygenate must be introduced in huge quantities to meet RFG demand. The only viable near-term solution involves replacing much of the M*t*BE currently in gasoline with ethanol. Ethanol has been used as a gasoline additive in parts of the country, especially the Midwest, for some time. While its use in the Northeast has been minimal to date, some companies market small amounts of ethanol-blended gasoline in the region.

REFORMULATING GASOLINE WITHOUT M*t*BE

The federal RFG program includes two types of requirements: emission performance standards and fuel specifications. All RFG must now comply with the more stringent Phase II emission performance standards that took effect January 1, 2000. Given the different properties of these oxygenates, refiners cannot simply replace M*t*BE with ethanol on a gallon-per-gallon basis. In addition to complying with the oxygenate requirement, refiners must ensure that RFG without M*t*BE also meets emission performance standards and fuel quality parameters such as octane and front-end volatility as measured by Reid Vapor Pressure (RVP). Proper octane is critical to vehicle performance; volatility affects both vehicle performance and emissions. Refiners face two main challenges in producing RFG with ethanol instead of M*t*BE: (1) the need to lower the volatility of the baseline gasoline to accommodate the addition of ethanol and (2) the need to make up the octane and volume loss associated with M*t*BE removal.

The RVP of all gasoline (reformulated and conventional) sold in the summertime is regulated for air quality purposes. Unlike M*t*BE, which has relatively low vapor pressure, adding small amounts of ethanol raises the volatility of the gasoline into which it is blended. The addition of ethanol to blendstock, at 2 percent oxygen by weight, raises the RVP of the gasoline by about 1.0 pound per square inch (psi). Volatility control is a critical part of all refiners' strategy to comply with the VOC performance standard of the RFG program. Producing low volatility blendstock to accommodate ethanol is technically feasible but is likely to increase the cost of gasoline. Moreover, the inadvertent mixing or "co-mingling" of ethanol-containing and ethanol-free blends in vehicle fuel tanks results in increased evaporative emissions. This is an issue of concern in the Northeast where both RFG and conventional gasoline are marketed.

Gasoline with a higher octane rating is more resistant to engine knock. This is the primary characteristic that distinguishes various grades of gasoline (e.g., regular vs. premium). A gasoline's octane rating is a function of the chemical composition of the blend. Oxygenates such as ethanol and M*t*BE are valuable blend components due to their high octane, anti-knock characteristics. In fact, M*t*BE was first blended in gasoline as an octane enhancer when lead was phased-out. Both M*t*BE and ethanol are less toxic than many other high-octane components of gasoline, such as benzene.

While ethanol has a slightly higher octane rating than M*t*BE, it also has substantially higher oxygen content; ethanol at 5.7 percent by volume provides the same by-weight oxygen content as M*t*BE at 11 percent by volume. Consequently, if blended at the RFG minimum, ethanol is less effective at displacing and diluting other toxic octane-enhancing constituents and may result in a moderate increase in toxic air emissions absent regulatory action. Further, because less ethanol is needed per gallon of RFG, other high-octane constituents will be needed to make up for the octane loss associated with removing M*t*BE.

Toxic aromatic compounds are the most likely high-octane replacement, which creates the potential for air toxic emission increases during the transition from M*t*BE to ethanol. High-octane compounds such as benzene and toluene are also a threat to water resources when spilled or leaked into the environment. Therefore, reformulation decisions that affect the amount of these compounds in gasoline also present water quality-related health and environmental implications.

PUBLIC HEALTH IMPACTS

Gasoline is a complex mixture containing hundreds of compounds, many of which are known or suspected human carcinogens. The public can be exposed to these pollutants through both air and water pathways. Given current information, ethanol appears to be one of the least toxic of the major components of gasoline when considering common toxicological endpoints, such as carcinogenicity and central nervous system depression. However, the potential for other adverse impacts, including developmental effects, of large-scale exposure to low levels of ethanol is uncertain. At atmospheric concentrations above health protective thresholds, some gasoline constituents are also severe respiratory irritants that may exacerbate asthma and other respiratory diseases. The pollutants associated with gasoline-powered vehicles are also significant contributors to ozone and fine particulate matter formation. Studies have found strong correlations between the introduction of cleaner-burning gasoline and reduced concentrations of ozone, ozone precursors and air toxics monitored in the ambient air.

Gasoline spilled and leaked into the environment is a major source of water pollution. At elevated levels, gasoline and its constituents can adversely affect the quality of drinking water, pose a threat to public health and threaten aquatic life. Health-based water quality standards have been established for a number of gasoline-related pollutants including benzene, toluene, ethylbenzene and xylene (the so-called BTEX compounds).

Evaluating the potential public health impacts associated with a shift from M*t*BE to ethanol requires a complex assessment that evaluates public exposure to both potentially toxic compounds in the air and water. The air quality analysis must evaluate potential changes in emissions of ozone and particulate precursors, as well as hazardous air pollutants (HAPs). The health impacts of direct ethanol emissions and the change in the emissions of other pollutants of concern that occur as a consequence of substituting ethanol for M*t*BE must also be evaluated. Further, the impacts associated with producing and transporting ethanol into and within the region must be considered.

While attempting to address each of these issues, NEIWPCC and NESCAUM focused this effort on evaluating the direct health effects associated with introducing a significant amount of ethanol into the region's gasoline supply. The analysis evaluates the health impacts of ethanol, predicts public exposure through air and water pathways, and compares these levels of exposure to endogenous levels of ethanol that are naturally produced in the body. A draft Water Comparison Value associated with neurotoxic effects from prenatal ethanol exposure is also presented.

Public Health Risk from Environmental Exposure to Ethanol

Ethanol is a clear, colorless liquid with an odor threshold of approximately 80 parts per million or 0.15 milligrams per liter (mg/L). This compound has numerous industrial uses and is widely consumed in alcoholic beverages. The potential health effects following ingestion of high concentrations of ethanol have been well studied. However, the potential adverse effects associated with repeated exposure to environmentally relevant concentrations are not well understood.

In humans, chronic exposures to elevated concentrations of ethanol have been shown to produce liver abnormalities, damage heart tissue and adversely affect the neurological system. Brief, high dose exposure to ethanol during pregnancy has long been associated with pronounced adverse developmental effects in newborns (fetal alcohol syndrome). More frequent lower concentration exposures to ethanol during pregnancy have been associated with behavioral alterations (fetal alcohol effects). The ingestion of high concentrations of ethanol over time has also been linked to cancers of the liver, oral cavity, pharynx and larynx. Chronic exposure to moderate to high concentrations of ethanol has also been shown to cause changes in blood cellularity that may alter an individual's immune response.

This study employed a "margin of exposure" analysis to compare predicted blood ethanol concentrations under various environmental exposure scenarios to a range of endogenous blood ethanol concentrations. The following exposure pathways were considered: inhalation during refueling; breathing ambient air containing ethanol; ingestion of contaminated water; and inhalation of household air, including the contribution from the shower/bath in a house with contaminated water. To bound the range of possible risks, several exposure scenarios using different concentrations of ethanol in the indoor and outdoor air and contaminated water were evaluated.

The results of the margin of exposure analysis indicate that direct inhalation exposure, even in the worst-case scenario, will not substantially add to existing endogenous levels of ethanol in the blood. These results suggest that direct exposure to ethanol as a consequence of its use in gasoline is unlikely to present significant new health risks to the general public. These findings are consistent with studies conducted by the Health Effects Institute and the California Office of Environmental Health Assessment that also concluded the potential public health risk from direct exposure to fuel ethanol was minimal. However, additional research is needed to assess low-level ethanol exposure on neurodevelopmental effects and health effects in sensitive subpopulations that metabolize ethanol or its byproduct, acetaldehyde, less efficiently.

Health Impacts of Ethanol By-Products and Other Air Toxics

Reformulation decisions associated with removing M*t*BE from RFG will change the toxic emission characteristics of a vehicle operating on these fuels. The presence of ethanol in gasoline spilled or leaked into the environment may also increase the risk of water pollution from benzene, toluene and other gasoline compounds because the microbes that breakdown gasoline in the soil preferentially degrade ethanol compared to other fuel components. This section summarizes the potential health impacts of possible changes in emissions of various hazardous air pollutants when ethanol replaces M*t*BE in gasoline.

Outdoor levels of air toxics regulated by the RFG program—benzene, 1, 3-butadiene, acetaldehyde, and formaldehyde—currently exceed health-based guidelines in many parts of the Northeast. Measured levels of M*t*BE in the air are about one-half the health protective threshold. There are no comparative data for the Northeast on ambient ethanol concentrations since no areas use much ethanol-blended gasoline.

The Phase II RFG toxics performance standard requires a 21.5 percent reduction in the combined mass emissions of benzene, acetaldehyde, formaldehyde, 1,3-butadiene and POM. Partly as a consequence of M*t*BE use, refiners have over-complied with the RFG toxic emission performance standard.[2] Even under Phase I, which required a 16.5 percent reduction, RFG sold in the Northeast achieved toxic reductions of about 35 percent. For the reasons described above, refiners may not continue to voluntarily over-comply with the toxic standard if M*t*BE use is substantially constrained. The transition to ethanol could therefore result in a significant increase in mass toxic emissions from RFG. The USEPA recently promulgated a mobile source air toxics rule as required under Section 202(l) of the Clean Air Act, which prevents refiners from increasing the average toxicity of the gasoline they sell nationally above current levels. While this regulation provides overall national protection, it does not necessarily protect against increased toxic emissions in a given state or region. Additional regulatory requirements such as the lowering of sulfur levels in gasoline will provide toxic reductions that refiners can take advantage of to offset toxic increases that may result in the transition away from M*t*BE.

The other primary air toxic concern relates to changes in ambient levels of acetaldehyde and formaldehyde. Ambient values for both toxins are currently above health protective thresholds throughout much of the Northeast. Both of these HAPs are probable human carcinogens and respiratory irritants that may exacerbate asthma. Vehicles running on M*t*BE-blended gasoline produce high rates of formaldehyde emissions and those running on ethanol-blended fuel produce high rates of acetaldehyde emissions. Some of the adverse health impacts from ethanol-related increases in acetaldehyde emissions will be offset by a corresponding decrease in formaldehyde emissions as M*t*BE is removed from gasoline. USEPA's Complex Model, which is used to certify RFG compliance, predicts that acetaldehyde emissions will increase by 50 to 70 percent if ethanol replaces M*t*BE. Formaldehyde emissions are predicted to decrease by 15 percent under this scenario.

While ethanol's role in increasing acetaldehyde emissions is a potential public health concern, monitoring data are insufficient to evaluate trends in ambient levels of acetaldehyde emissions in areas where ethanol-blended gasoline has been introduced. Consequently, it is difficult to predict the degree to which increased tailpipe emissions of acetaldehyde from ethanol blends will translate to changes in ambient concentrations of this pollutant in the Northeast. A study in California concluded that increased vehicle emissions due to ethanol use would not significantly change ambient acetaldehyde concentrations. Rather, the California study identified aromatic compounds and olefins as being primarily responsible for the formation of formaldehyde and acetaldehyde in the air. However, the California airshed is different from that in the Northeast and their study did not address microenvironments where elevated exposures are more likely. Region-specific factors that would need to be considered in performing a comprehensive modeling analysis of net impacts for the Northeast include the composition of the vehicle fleet, the number of vehicle miles traveled, the contribution of other pollutants from motor vehicles and other sources, the likely composition of both conventional and reformulated gasoline given different supply/demand assumptions for competing fuel constituents, the potential for co-mingling and other indirect emissions impacts (including potential effect on the relative volatility of benzene), and local atmospheric conditions.

Another concern with regard to air toxics is the possibility that the volatility of ethanol can increase evaporative emissions of benzene, especially in older vehicles. When combined in laboratory settings, ethanol and benzene have been shown to be capable of forming an azeotrope that has a lower boiling point and higher vapor pressure than either ethanol or benzene alone. As a result, some studies suggest that the addition of ethanol could significantly increase hot soak benzene emissions (for example, one study using a 10 percent ethanol blend showed a forty five percent increase in evaporative benzene emissions relative to non-ethanol blended gasoline).

Ozone Impacts

Ozone is a powerful respiratory irritant that affects large segments of the population in the summertime, especially the elderly, children and individuals with existing respiratory problems. Gasoline-powered motor vehicles emit approximately one-third of ozone-forming VOCs and NOx in the region. RFG has proven to be an effective strategy for reducing these ozone precursor emissions.

The wide-scale replacement of M*t*BE with ethanol could result in increased ozone precursor and toxic emissions from vehicles operating on either RFG or conventional gasoline. This may include increased: (1) tailpipe NOx emissions; (2) evaporative VOC and toxic emissions; and (3) indirect transportation emissions of NOx, particulate matter and toxics.

There is some evidence that NOx emissions from ethanol-blended gasoline may be higher than for non-oxygenated blends, especially if ethanol is added at more than the 2 percent weight minimum specified by the current RFG program. Importantly, these impacts may not be reflected in the Complex Model. Specifically, available empirical data indicate that NOx emissions are higher for 10 percent ethanol blends compared to current M*t*BE blends. Tax policies, as well as supply and demand considerations, may provide refiners with an incentive to blend ethanol at 10 volume percent (which translates to an oxygen content of 3.5 percent by weight), in which case potential adverse NOx emissions impacts would be of particular concern.

According to the National Research Council (NRC) the reactivity of exhaust emissions (or amount of ozone produced per mile) from motor vehicles operating with ethanol-blended RFG is not significantly different than tailpipe emissions from vehicles using M*t*BE-blended RFG. However, the NRC concluded that both the mass and reactivity of evaporative emissions from motor vehicles using ethanol-blended RFG were higher than those emissions associated with M*t*BE-blended RFG. This finding is due, in part, to the assumption that the RVP is higher in ethanol-blended RFG. This effect could be minimized if the RFG program's VOC performance standard is maintained; not weakened as EPA recently allowed for ethanol-blended RFG. Citing concern over predicted cost increases in Midwest gasoline, EPA proposed on March 15, 2001 to relax the VOC performance standards for RFG blended with ethanol. An EPA press release on that date quotes Administrator Whitman stating, "…I recently directed EPA staff to finalize an upward adjustment to the VOC standard…which will provide greater flexibility than the 0.2 pounds [RVP waiver] that was originally proposed." In plain terms, EPA has opted to weaken the environmental performance of RFG blended with ethanol due to cost concerns. If ethanol cannot be relied upon as a cost-effective means to satisfy the RFG performance requirements in states where it is produced, Northeast states have reason to fear the potential cost implications and/or weakening of health protections needed to accommodate an RFG ethanol mandate in our region.

Evaporative emission impacts are likely to be more significant with conventional gasoline because 10 percent ethanol blends are given a full one-pound volatility waiver and there are no corresponding emission performance standards for conventional gasoline. Further, the co-mingling effect will result in greater evaporative emissions in areas where both ethanol-blends and ethanol-free gasoline is sold. Finally, there is evidence to suggest that ethanol blends may produce a modest increase in evaporative emissions from lines, hoses and the engine crankcase, especially in older vehicles. Because ethanol molecules are relatively small, they can more easily permeate rubber, plastics and other materials found in components of the fuel delivery system. Recent vehicle standards address this issue but do not preclude increased emissions from permeation effects in older vehicles. A related issue that is relevant to newer vehicles is the potential for ethanol blends to degrade the performance of on-board vapor recovery systems over time. Specifically, ethanol blends could reduce the working capacity of the carbon canisters used in these systems because of ethanol's propensity to be tightly held by activated carbon and its tendency to attract water. Additionally, ethanol may also affect the efficiency of Stage II enhanced vapor recovery (EVR) controls.

NATURAL RESOURCE IMPACTS

Water Quality

The rationale for transitioning to ethanol is predicated primarily on the desire to protect water resources from the threat posed by M*t*BE. This study examined the potential for releases of both pure (neat) ethanol and ethanol-blended gasoline into the environment throughout their life cycles. Pure ethanol releases can occur at an ethanol manufacturing facility, along the transport system, or at the bulk terminals where it is stored and blended. Ethanol-blend gasoline spills can occur from the blending point, to gasoline retail facilities (aboveground and underground storage tanks), all the way to the point of end use (e.g., automobiles, lawnmowers, etc.).

Both ethanol and M*t*BE exhibit a relatively high solubility in water and high mobility in the subsurface. Once released to the environment, alone or in a gasoline mixture, both ethanol and M*t*BE readily dissolve in rain, surface water, and groundwater. Ethanol, which is more soluble, is completely miscible in water (100 percent soluble, compared with 4 percent for M*t*BE).

The primary differences between ethanol and M*t*BE with regard to their expected impacts on the subsurface environment relate to: (1) their initial concentration in the aqueous plume; (2) the very different rates at which they biodegrade; and (3) possibly their residence time in the non-aqueous phase. Because M*t*BE is recalcitrant to biodegradation, it is able to migrate significant distances from the point of release. Consequently, it has the potential to negatively impact groundwater quality over larger areas for extended periods of time. Ethanol is likely to biodegrade rapidly, because microbes preferentially degrade it compared to other components of gasoline. However, its actual behavior in the environment is not well documented. A release of neat ethanol could degrade in a period of anywhere from several days to two years.

Three of ethanol's environmental transport properties are of potential concern: (1) a cosolvency effect that makes other gasoline constituents more soluble in groundwater; (2) depletion of oxygen and other nutrients in groundwater due to rapid biodegradation of ethanol that inhibits the degradation of other, more toxic components in gasoline; and (3) a surface tension effect that takes place when ethanol, in contact with a layer of gasoline on top of the water table, causes greater lateral spreading of the gasoline.

The rapid biodegradation of ethanol depletes the oxygen and the anaerobic electron acceptors in soil and water. This phenomenon slows the biodegradation of other compounds in gasoline and can result in more persistent BTEX plumes. By contrast, M*t*BE does not interfere with the natural biodegradation of the other gasoline components. Laboratory studies and mathematical models suggest the potential for ethanol-blended gasoline to cause the toxic BTEX compounds of gasoline to travel up to 2.5 times farther than in the absence of ethanol.

It is generally believed that under typical conditions, ethanol degrades rapidly when released to the environment. However, a recent study involving a controlled release of ethanol-blended gasoline into a sand aquifer in Brazil showed an ethanol decay rate that was 100 times slower than predicted in laboratory studies. This suggests that, at least under certain conditions, ethanol can exist in the environment far longer than previously thought. However, the amount of ethanol used in Brazilian gasoline is higher than that expected in the northeastern U.S. and any effects resulting from the depletion of oxygen, nutrients, etc. would be sensitive to the concentration of ethanol in gasoline.

If spilled in a stabilized zone of gasoline-contaminated soil (e.g., at oil terminals), ethanol can remobilize the BTEX compounds and other gasoline components at the site. This may cause or exacerbate contamination of groundwater and nearby wells. Because of the cosolvency and oxygen depletion factors associated with ethanol, there is concern that a significant and continuing release (e.g., from a significant undetected UST leak) could result in an extended BTEX plume.

From a water quality protection standpoint, the potential adverse impacts associated with ethanol are clearly less problematic than for M*t*BE-blended gasoline. However, this evaluation is based on predictions from scientific estimations of what will happen to soil and groundwater in the event of a release of ethanol-blended gasoline, not field data and experience. Ethanol is likely to have less adverse impacts than M*t*BE in small-volume spill scenarios. The relative impacts of large-volume spills are hard to generalize due to the uncertainties in quantifying the effects of ethanol on BTEX plume length, the concentration of terminal electron acceptors, and secondary effects on groundwater quality, such as increased levels of dissolved iron.

Effects of Ethanol on Aquatic Life

Ethanol can be toxic to aquatic life at high concentrations. However, due to its chemical properties and the ability of most organisms to breakdown and eliminate it from their bodies, ethanol is not likely to bioaccumulate or bioconcentrate in the tissues of living organisms. The breakdown of ethanol in surface waters through biological and chemical processes could potentially result in the consumption of significant quantities of dissolved oxygen in the surface water body. Depending on the conditions in the surface water body and the amount of ethanol introduced, it is possible that sufficient amounts of dissolved oxygen could be consumed to adversely affect aquatic life, potentially leading to fish kills. Spills of ethanol into surface water bodies that have low aeration rates (e.g., ponds, lakes and large, nonturbulent, rivers) can deplete oxygen and asphyxiate fish and other aquatic organisms. Under acute exposure conditions, ethanol is 3.7 times less toxic to aquatic life than M*t*BE. Over a longer period of exposure, ethanol is thought to be similar, although somewhat less toxic, than M*t*BE in terms of its impact on aquatic life.

Remediating Ethanol and Ethanol-Blend Spills

The presence of ethanol is expected to have a minimal impact on the technologies or cost associated with soil remediation in the event of a gasoline spill. Much of the technology developed to clean-up gasoline and M*t*BE in soil should work in remediating spills of neat ethanol and ethanol-blends. However, until these technologies are field tested, it is difficult to determine the relative cost and efficacy of the various options.

The potential impact on groundwater remediation is less well understood. Due to its high solubility, treatment technologies that rely on the physical separation of ethanol from water will not be effective. For example, carbon filters that are widely employed to remove other gasoline contaminants from private wells will not remove ethanol. On the other hand, since ethanol is highly biodegradable, biological treatment technologies offer significant promise. Because of the potential for high concentrations of ethanol in plumes and the resulting high levels of BOD, in-situ bioremediation technologies would have to be scaled-up relative to those currently used.

DEVELOPING AN ETHANOL INFRASTRUCTURE

Overview

M*t*BE is typically blended into gasoline at the refinery and does not require special handling within the distribution system. By contrast, because of ethanol's affinity for water, ethanol-containing gasoline would tend to pick up the small amounts of water that can accumulate over time in pipelines and storage tanks as a result of condensation or minor contamination. These actions would unacceptably degrade the quality of ethanol-blended gasoline delivered through existing pipelines.

To avoid this problem, 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. Consequently, segregated ethanol storage tanks will be needed at distribution terminals. Special blending equipment will also be needed to allow ethanol to be loaded onto tanker trucks simultaneously or in sequence with gasoline. Besides incurring additional costs, these infrastructure needs may present other challenges, including siting and regulatory issues. For example, space constraints may prove to be an important obstacle in siting new storage tanks at petroleum refinery and distribution facilities.

Pipeline transport of ethanol between the Midwest and East Coast is likely to remain substantially constrained in the near-term, though some stakeholders have argued that it may be a viable option over the longer-term. The near-term alternatives—moving ethanol by rail, tanker truck, or barge—present a variety of logistical and environmental implications. For example, to accommodate the amount of ethanol that would be needed to meet RFG demand, barge, rail and truck facilities would need to be added or expanded at bulk terminal and port facilities in the region. Additionally, each of these modes of transport relies on vehicles or vessels powered by large diesel engines that generate significant amounts of fine particulate matter, NOx, and HAPs.

Ethanol Storage and Handling

Ethanol, both as a pure product and blended with gasoline, introduces different concerns for tank and piping components than M*t*BE-blended gasoline. However, these problems and their solutions are fairly well understood. Concerns with storing ethanol and ethanol-blends relate primarily to: (1) compatibility issues with storage tank components; (2) ethanol's propensity to cause water to separate out of gasoline and settle at the bottom of a tank; (3) the fact that ethanol is a solvent and will loosen rust and deposits from the interior walls of storage systems; and (4) the fact that ethanol is electrically conductive and when added to gasoline causes the blend to become conductive.

The materials used to fabricate underground storage tank and aboveground storage tank (UST/AST) systems have evolved over time to accommodate the storage of ethanol and ethanol-blended fuels. The introduction of ethanol into the Northeast gasoline supply will come with the added cost associated with retrofitting some of the region's older tank systems to make them ethanol compatible. UST/AST components that are not compatible with ethanol-blended fuels may cause system failures and/or produce leaks. Experience with UST programs in the Northeast suggest that many owner/operators will not have their facilities properly evaluated for compatibility prior to the introduction of ethanol-blended fuels into their tank systems.

Caution must be taken with the storage of ethanol-blended fuels in single-walled fiberglass reinforced plastic tanks fabricated prior to January 1, 1984. Questions also exist concerning the compatibility of ethanol-blends with certain tank/dispensing system components and materials including: lining materials, secondary containment materials, adhesives, glues, sealants and gaskets, as well as any polymer or elastomer compounds found on dispensing or monitoring devices such as automatic tank gauge (ATG) probes. Some component materials (e.g., cork and Buna-N) used in dispensers, submersible pumps, and other distribution equipment that handles ethanol-blended gasoline may have long-term compatibility problems. The presence of ethanol in gasoline may also impair the operation of capacitance ATG probes because of the increased electrical conductivity of ethanol-blended gasoline.

The introduction of ethanol into gasoline enhances the suspension of water and deposits scoured or cleaned from UST/AST systems. Water and scoured deposits not eliminated from UST systems could cause or contribute to premature failure of leak monitoring systems, submersible pumps, fuel dispensers, piping, hoses, nozzles and swivels.

Most automotive manufacturers approve the use of ethanol-blended fuels. Many non-automotive engine manufacturers now address oxygenated fuels and permit or approve the use of ethanol-blend fuels. However, some older engine models may have components (e.g., swollen carburetor floats) that have exhibited compatibility problems with alcohol. Many manufacturers, however, provide recommendations for handling and modifying their equipment when ethanol-blended fuel is used. Given the potential for ethanol to carry contaminants from tanks and pipes, there may be greater likelihood for contaminated gasoline that could damage engines using this product. Further, water absorbed by ethanol may separate in the gas tank, which could result in poor engine operation and may cause fuel lines to freeze in the winter.

COST OF REPLACING M*t*BE WITH ETHANOL

Fuel Reformulation Costs

Fuel formulation changes associated with eliminating M*t*BE are likely to increase the cost of producing gasoline because: (1) they will necessitate process changes and equipment modifications at the refinery and (2) replacement blend components such as alkylate and ethanol are more expensive than M*t*BE. The magnitude of these costs is highly sensitive to a number of interdependent variables and is therefore difficult to forecast with accuracy. Important factors include the timeframe over which fuel changes are phased in, the relative supply and demand for various fuel constituents, and the longer-term prospects for developing ethanol production capacity nearer to the areas where RFG use is concentrated.

A number of organizations have sponsored studies of the likely cost impacts of a large-scale shift from M*t*BE to ethanol. However, most of these assessments have focused on cost impacts nationally or in California. In 1999, the U.S. Department of Energy (USDOE) estimated that the average cost of RFG produced at east coast refineries would increase by 3.9 cents per gallon if all M*t*BE were replaced by 2004 under a nationwide ban on ethers (including M*t*BE) and a continuation of the existing oxygenate mandate.[3] The USDOE results assume that refiners will meet only the minimum regulatory requirements for toxic air emissions, rather than achieving the current level of reductions (which would have the effect of increasing actual emissions relative to current levels).

More recent national-scale analyses by the USDOE's Energy Information Administration (EIA) in 2000 produced higher estimates of the incremental cost of banning or limiting M*t*BE use. Under a range of scenarios, EIA estimated that the average cost of producing gasoline will increase from 2 cents to 8 cents per gallon in the 2004-2005 timeframe as M*t*BE use declines. The EIA results suggest that the incremental cost of maintaining the oxygen mandate is between 4 and 5 cents per gallon compared to eliminating M*t*BE and lifting the mandate. These national estimates may understate costs in the Northeast, which could vary significantly depending on regional supply constraints. Moreover, the EIA estimates assume annual average fuel requirements and may therefore minimize the seasonal cost impacts of using ethanol in the summer when RVP is an issue.

The California Energy Commission (CEC) has also conducted comprehensive analyses of likely cost impacts, though these are generally specific to California.[4] A 1998 CEC analysis assumed a ban on M*t*BE in three years with continued oxygenate requirements under the California RFG program. It included detailed estimates of the added costs of using ethanol, such as those associated with modifying or adding infrastructure at refineries and distribution terminals, as well as the costs of transporting ethanol from the Midwest and other areas to the West Coast. The CEC estimated an incremental cost increase of 6.1 to 6.7 cents per gallon, with total costs in California ranging from $902-991 million per year. The CEC also looked at implementing an M*t*BE ban over a longer, six-year timeframe (i.e., by 2005). This scenario produced lower incremental costs ranging from 1.9 to 2.5 cents per gallon, with total costs ranging from $298-392 million per year. The CEC concluded that a nationwide phase-out of M*t*BE in the intermediate term (3 year) could increase the incremental cost of gasoline in California to 11.7 cents per gallon, while incremental long-term (6 year) costs could rise to 3.7 cents per gallon. Note that the latter figure is similar to USDOE's 1999 incremental cost estimate of 3.9 cents per gallon, assuming a 2004 (rather than 2005) phase-out of M*t*BE.

Variable costs, which include refinery operating costs and the costs of various blendstocks and additives, are predicted to be responsible for over 70 percent of total incremental cost increase associated with replacing M*t*BE with ethanol in the intermediate-term and for 50 percent of this increase in the long-term. Other incremental costs in the CEC analysis include the need for additional blendstock tankage and inventory, as well as the added terminal and transportation costs associated with ethanol blending. Finally, the CEC predicted that the modest mileage loss associated with ethanol's somewhat lower energy content relative to M*t*BE would add 0.6 to 1 cent per gallon to the incremental cost to consumers.

Because M*t*BE now makes a significant volume contribution to overall gasoline supplies in the Northeast and elsewhere, phasing out or substantially reducing M*t*BE use in the near term could cause volume shortfalls which by themselves would lead to higher fuel costs. Moreover, blendstock changes necessitated by formulating ethanol blends to meet existing fuel performance requirements could further exacerbate such shortfalls. For example, this would be the case if the refiners were forced to remove other volatile (and generally less expensive) gasoline constituents, such as pentanes and butanes, to compensate for ethanol's volatility impacts during the summer months. The CEC recently warned that California's plans to phase out M*t*BE could result in overall gasoline production shortfalls of 6 to 10 percent in 2003.

Total gasoline consumption in the Northeast is expected to exceed 15 billion gallons annually in the next few years. Hence an incremental increase of 5 cents per gallon could translate into additional regional costs of $700 million annually. However, actual cost impacts are likely to be highly sensitive to the supply and availability of ethanol and low-RVP blendstocks. Total new ethanol demand from the Northeast and California alone could approach 2 billion gallons per year. Unless fuel ethanol was shifted out of other markets where it is currently being used, existing capacity would have to roughly double to meet this additional demand. Finally, ethanol currently benefits from federal tax subsidies (in the form of a partial exemption from the federal fuel excise tax and an income tax credit) that amount to 53 cents per gallon. If these subsidies were to be reduced to offset the budgetary impacts of a major expansion of ethanol use, the cost faced by refiners would likely increase, as would prices for ethanol-blended gasoline at the pump. On the other hand, if subsidies are not reduced, the impact on state highway funds could be substantial.

Similarly, blending ethanol-containing RFG to meet existing RVP limits and the VOC performance standard can be expected to present substantial cost and supply hurdles for refiners. It has been estimated that to meet these limits, a base gasoline with an RVP as low as 5.5 to 5.7 psi may be needed. Many refiners assert that the costs of producing such a blendstock would be prohibitive in the near-term and would exacerbate the fuel supply and price volatility problems. Even Midwest refiners serving the Chicago area have in the past needed to switch from ethanol to M*t*BE in the summer months because the additional VOC reduction requirements of the Phase II RFG program effectively preclude the use of ethanol.

Infrastructure Costs

The cost impact analyses discussed in the previous section generally attempt to capture some or all of the costs of developing an ethanol infrastructure. New investments are anticipated because ethanol's unique properties—notably it's affinity for water—necessitate different handling and transport methods than have been used for M*t*BE.

The CEC analysis concluded that it would cost as much as $60 million and take from 18 to 24 months to complete the necessary modifications to storage tanks, unloading facilities and blending equipment in California. The most expensive modifications are likely to involve the installation of blending equipment at distribution terminals—which the CEC estimated could cost close to $25 million, involve modifications to nearly 150 truck loading lanes and require up to two years to complete. Modifying existing storage tanks to hold ethanol and building new tanks was estimated to cost an additional $16 million, while the modifications needed to receive ethanol at distribution terminals—including upgrading and expanding rail facilities and truck unloading facilities—would cost an additional $19 million. Assuming that 2004-2005 ethanol demand in the Northeast would be roughly 50 percent that of California's and that necessary capital investments in the distribution infrastructure can be scaled accordingly, suggests that costs in the Northeast would be on the order of $30 million. These additional distribution infrastructure capital costs would tend to raise the cost of delivering gasoline to the pump by 0.1 cents per gallon.

PRODUCING BIOMASS ETHANOL IN THE NORTHEAST

Given the dramatic increase in ethanol demand likely with a phase-out of M*t*BE (especially under a continued RFG oxygenate mandate) and the supply constraints noted previously, lowering the long-term cost of ethanol to Northeast consumers may depend to a significant extent on the successful development of indigenous ethanol production capacity using waste biomass or dedicated biomass feedstocks. This would not only help to overcome the supply, transportation and distribution hurdles noted above, it could boost the region's economy by keeping dollars in the Northeast that would otherwise flow to energy producers elsewhere in the country and overseas.

The potential for developing ethanol production capacity in the Northeast rests on the ability to commercialize ethanol production from cellulosic feedstocks such as forestry and mill waste, waste paper, crop residues and dedicated energy crops, rather than corn. While such ethanol production processes could potentially provide significant environmental and economic benefits, they have not been widely commercialized to date. Biomass ethanol production now contributes only a small fraction of the amount of ethanol produced from corn; about 60 million gallons per year compared to over 1 billion gallons annually from corn.

Potential for Biomass Ethanol Production in the Northeast

The following factors affect the potential for commercially viable ethanol production from any particular feedstock at a given site: (1) the amount of feedstock available and the degree to which economies of scale can be realized; (2) the cost of feedstocks (and their competing uses); (3) the potential yield from different feedstocks and the complexity of the conversion process; (4) the cost of capital; and (5) a host of site-specific factors including the difficulty of siting and permitting a facility, public acceptance, etc. Based on available quantities and current feedstock costs, waste paper, paper sludge, and cheese whey appear to be the most likely feedstock candidates for near-term ethanol production in the Northeast. Over the longer term, forestry wood wastes appear to have high potential as a regional ethanol feedstock. A study by the Council of Northeast Governors estimates that waste paper alone could support over 400 million gallons per year (gpy) of ethanol production in the region. In the near term, cheese whey and paper sludge could supply an additional 40 million gpy. Over the longer term, forestry wood waste could support an additional 470 million gpy, for a total "high potential" production capacity of 900 million gpy. This amount is roughly equal to the quantity of ethanol that might be required in the Northeast over the next several years under an M*t*BE phase-out and continued oxygenate mandate.

Status of Efforts to Commercialize Cellulosic Biomass Ethanol Production

The existing commercial ethanol industry is almost entirely corn-based. It produces from 1.2 to 1.5 billion gallons of corn ethanol per year and consumes about 6 percent of domestic corn production. Corn ethanol is produced through either dry or wet milling processes. Wet milling (which currently accounts for about two-thirds of domestic production) also produces corn oil, corn gluten meal, and corn gluten feed; dry milling also produces distillers' grain and solubles (DGS) which is sold as animal feed.

In recent years, considerable research has been devoted to the development of commercially viable ethanol production processes using cellulosic (woody) biomass feedstocks rather than grain feedstocks. Successful commercialization of such processes would greatly expand long-term domestic ethanol production potential by allowing for the use of a greater variety of feedstocks. Moreover, most analysts believe cellulosic ethanol could achieve significantly lower production costs and substantially greater overall environmental benefits. The chief cellulosic processes available at this time use either acid hydrolysis or enzyme technology to convert cellulose to sugar for fermentation into ethanol. These processes require substantially less energy input than current corn-based production. In addition, the unfermentable biomass components—primarily lignin—can be used to cogenerate steam and electricity at the ethanol plant.

Cellulosic ethanol is not currently produced on a commercial scale, though a few cellulosic plants are under construction or in the planning stages. The U.S. Department of Energy's Office of Fuel Development estimates that new cellulosic production capacity of over 60 million gallons per year is currently planned for start-up in the 2001-2003 timeframe. This capacity includes a 10 million gallon per year facility for producing ethanol from municipal solid waste in New York State. Based on current data and various market assumptions, the costs of commercial-scale cellulosic ethanol production are projected to decline from $1.40 per gallon in 2000 to less than $1.00 per gallon in 2010 and less than $0.80 in 2025. Total production could reach 1 to 2 billion gpy by 2010. Over the long run, government researchers have estimated that the theoretical market supply potential for cellulosic ethanol could be as high as 10 to 30 billion gpy (at feedstock costs in the range of $30-40 per dry ton).

Climate and Land-Use Impacts of Increased Biomass Ethanol Use in Northeast

Biomass ethanol has long attracted interest as a renewable fuel that could potentially reduce fossil fuel dependence, improve national energy security, and reduce climate change impacts. Provided feedstocks are sustainably managed, any carbon released by the combustion of a biomass fuel is theoretically offset by the removal of an equivalent amount of carbon from the atmosphere through the re-growth of feedstocks. In practice, the climate picture is considerably more complex when agricultural inputs, production process energy inputs, and land use changes are taken into account.

Until recently the net climate impacts of corn-based ethanol were thought to be minimal given the relatively input intensive nature of corn cultivation and the energy intensity of the corn-to-ethanol conversion process. More recent analysis conducted by the Center for Transportation Research at Argonne National Laboratory[5] suggests that corn-based ethanol has positive net climate change and energy security benefits when recent improvements in agricultural productivity and corn-to-ethanol conversion efficiency are taken into account. However, these benefits are still substantially less than the benefits that could theoretically be realized from cellulosic ethanol production. The Argonne researchers concluded that whereas each gallon of corn ethanol could achieve net greenhouse gas benefits of 12 to 26 percent relative to an equal quantity of gasoline, cellulosic ethanol could achieve greenhouse gas benefits from 80 percent to more than 130 percent relative to gasoline. From an energy security standpoint, corn ethanol was found to reduce petroleum use by more than 90 percent and overall fossil energy use by over 40 percent, compared to gasoline. Meanwhile, it was estimated that the use of cellulosic ethanol could reduce petroleum use by close to 90 percent and overall fossil energy use by close to 100 percent.

In terms of land-use and other environmental impacts (fertilizer run-off, ecosystem diversity, and habitat preservation), cellulosic ethanol is expected to offer certain advantages relative to corn-based ethanol. This is largely because potential cellulosic feedstocks could encompass a greater variety of crop types that generally require less intensive cultivation and less agricultural input relative to corn and other grains. Nevertheless, it should be noted that general concerns have been raised about the potential ecosystem and land-use impacts associated with large-scale expansion of plantation-type dedicated biomass energy crops. Of course, to the extent that cellulosic ethanol production utilizes wastes and residues (whether municipal or food wastes, agricultural or mill residues, waste paper, etc.), land-use and other environmental impacts may be minimal or non-existent. Indeed these impacts could even be positive in cases where the diversion of biomass wastes for purposes of ethanol production relieves pressure on landfills or avoids other disposal options that have negative environmental impacts.

CONCLUSION

A host of important national policy goals support an increase in the use of ethanol including energy security and diversification, farm policy and global climate change. Improving urban air quality is at best a weak rationale for promoting increased ethanol use. Unfortunately, current policies aimed at maintaining the oxygen mandate in the federal RFG program seek to base future ethanol markets on this weakest link in the rationale for ethanol expansion. It is simply not possible to provide our citizens with clean air, clean water and low cost gasoline so long as the oxygen mandate remains in effect. For this reason, the Northeast states will continue to advocate for the removal of the oxygen mandate through statute or regulation while continuing to work with ethanol advocates like the Governor's Ethanol Coalition, the National Farmers Union, the Clean Fuels Development Coalition and the American Council for Ethanol to find reasoned approaches to expanding the use of ethanol as a motor fuel nationally.

Regardless of whether the oxygen mandate is repealed, maintained or altered, efforts to reduce the amount of M*t*BE in gasoline will result in a substantial increase in fuel ethanol use in the Northeast. This shift will come with attendant public health, environmental and economic consequences. While the air quality benefits of RFG could diminish somewhat if ethanol replaces M*t*BE, the program will continue to provide important public health benefits. Moreover, the potential adverse air quality impacts of shifting from M*t*BE to ethanol can be managed through thoughtful policy such as repealing the federal oxygen mandate, establishing appropriately stringent toxic emission standards for RFG, allowing refiners to annually average oxygen use on a national basis, and requiring both conventional gasoline and RFG blended with ethanol to meet the same RVP requirements as ethanol-free gasoline. These policies to maintain the full air quality benefits of RFG, eliminate M*t*BE from the fuel supply, and repeal the oxygen mandate can be implemented at a considerable cost savings when compared to the status-quo alternative which would impose a de-facto summertime ethanol mandate.

The use of ethanol in gasoline presents far less risk to drinking water and other aquatic resources than M*t*BE. Nevertheless, the Northeast states will need to be proactive in preparing the region's underground storage tank infrastructure for the introduction of ethanol. This may require upgrading older tanks and components that may not be ethanol compatible. The states also need to develop cost-effective remediation strategies to respond, where necessary, to spills of pure ethanol and ethanol blends.

If the oxygen mandate is retained in federal law, the economic consequences of replacing M*t*BE in gasoline with ethanol are likely to represent the greatest impact in the Northeast. Existing information suggests that producing RFG with ethanol will increase the per gallon cost by 3 - 11 cents in the near-term. The predicted cost increase declines with a longer M*t*BE phase out period. To put this impact in perspective, a one-cent per gallon increase in the cost of RFG translates to about 120 million dollars per year in the region. Since most RFG is produced outside the Northeast, increased gasoline costs will result in a substantial outflow of resources from the regional economy. Further, there may be significant adverse impacts on the state highway funds, due to the structure of the federal subsidy program to encourage fuel ethanol use. The development of ethanol production capability in the Northeast based on the cellulosic biomass offers an economic opportunity that could reduce the long-term cost and increase the economic and environmental benefits of fuel ethanol use in our region.

Given the regional nature of the gasoline distribution system, the Northeast states must coordinate with the oil and ethanol industries in planning and building an infrastructure to support the transport, blending and storage of ethanol. This significant undertaking must be properly sequenced with state or federal M*t*BE bans or phase-downs to minimize supply disruptions or gasoline price spikes.

The potential adverse air and water quality issues associated with the widespread introduction of fuel ethanol can be adequately managed through informed legislation, regulation and program implementation. However, unless the oxygen mandate is lifted the Northeast states will be forced to accept substantial increases in gasoline prices and/or a weakening in air quality protections to accommodate ethanol at an acceptable cost. For these reasons we urge the states to continue advocating for a repeal of the oxygen mandate while at the same time undertaking the infrastructure development necessary to support an imminent increase in ethanol use in our region.

HEALTH, ENVIRONMENTAL, AND ECONOMIC IMPACTS OF ADDING ETHANOL TO GASOLINE IN THE NORTHEAST

RECOMMENDATIONS

LEGISLATIVE AND REGULATORY INITIATIVES

- The Northeast states should continue to aggressively encourage Congressional action to lift the federal oxygen mandate for RFG.
- Pending effective Congressional action, a model oxygen waiver request to USEPA should be developed for use by the individual states.
- Any federal program requiring ethanol in gasoline must allow refiners and suppliers to meet their sales quotas nationally on an annual average basis. This flexibility will help ensure that ethanol is used where it makes economic sense and will promote the use of higher amounts of ethanol in the winter and lower amounts in the summer to minimize adverse air quality impacts.
- Federal mandates or incentives for ethanol use should provide additional encouragement for production from cellulosic biomass feedstocks.
- The states should support an elimination of the RVP waiver currently provided for ethanol-blended conventional gasoline and oppose imposition of any new waivers for conventional or reformulated gasoline.
- A regionally coordinated phase-out of M*t*BE in all gasoline should be pursued to minimize adverse economic impacts and enable the development of an adequate regional infrastructure for ethanol.
- The states should work with USEPA in developing regulatory revisions to the RFG program to prevent the potential for toxic emissions increases as M*t*BE is phased-down (e.g., adjust toxics performance standard to levels actually achieved under the program).
- The states should coordinate with the oil and ethanol industry in the timely development of an adequate ethanol infrastructure.
- States should seek further clarification of their authority, as well as that of USEPA to regulate fuel additives for public health and environmental purposes.
- The Northeast/Mid-Atlantic Fuels Task Force should focus its efforts on developing options for implementing the recommendations of this study.
- The states should assess the impacts and efficacy of the federal tax incentive that results in the use of higher concentrations of ethanol than are needed for air pollution control purposes.

RECOMMENDATIONS continued

HEALTH EFFECTS

- ▲ This summary analysis was performed in a limited time frame. A more thorough review of the literature and additional basic research is needed to better substantiate and support these findings.
- ▲ Additional studies of the health effects of low-level exposure to ethanol are needed, particularly to expand our understanding of where the threshold lies for neurodevelopmental effects.
- ▲ Additional modeling should be conducted to estimate ambient exposure to ethanol in order to better understand the distribution of exposures and the attendant public health risk. This analysis should include both short-term high exposures and chronic low level exposures in microenvironments, especially for at risk sub-populations.
- ▲ Additional research is needed regarding the toxicokinetics of low level ethanol exposure (including fetal and maternal blood levels) relative to typical background exposures from the diet and the response of sensitive subpopulations.
- ▲ Research is needed to assess the metabolic interaction between ethanol and other environmental pollutants (e.g., benzene) at environmentally relevant doses.
- ▲ As ethanol will not replace 100 percent of the volume of M*t*BE currently found in RFG, aromatics, olefins, and alkylates are seen as the likely additives that will be used to make up the volume. A further assessment of the public health characteristics and impacts of these additives is needed before the widespread introduction of ethanol reformulations.
- ▲ More research is needed to estimate the potential adverse health impacts due to increased evaporative emissions, combustion by-products and other emission changes associated with the use of ethanol blended gasoline.

ECONOMIC IMPACTS

- ▲ The states should coordinate with the U.S. Department of Energy, oil industry, and the ethanol industry in conducting detailed computer refinery modeling to predict the likely response of refiners to the elimination or reduction in M*t*BE use in the Northeast and the impact that such changes will have on emissions and the cost of producing gasoline.
- ▲ A variety of scenarios should be considered since the cost implications of lifting the current per gallon oxygenate mandate and replacing it with an annually averaged renewable fuels requirement could, for example, be much different from the cost implications of maintaining the current oxygen mandate while phasing out M*t*BE.
- ▲ A detailed analysis is needed of the infrastructure costs related to fuel ethanol use.

ENSURING THE INTEGRITY OF UNDERGROUND STORAGE TANK SYSTEMS

- ▲ To prevent releases due to the degradation of non-compatible material in UST systems, a program should be established to require UST owners and operators to obtain certification that UST systems are compatible with ethanol-blended fuels.

HEALTH, ENVIRONMENTAL, AND ECONOMIC IMPACTS OF ADDING ETHANOL TO GASOLINE IN THE NORTHEAST

RECOMMENDATIONS continued

- ▲ The USEPA's Office of Underground Storage Tanks and the states should coordinate with affected industries in developing a guidance document to standardize the process by which UST owner/operators, or their contractors, assess the compatibility/functionality (e.g., capacitance probes) of their storage tank systems with ethanol-blend fuels. The document should inform owner/operators of proper operating procedures for the continuous management of storage tank systems, with a focus on the initial conversion of facilities to ethanol-blended fuels and problems associated with ethanol introduction.
- ▲ State and/or the federal government should look for ways to increase inspection resources during the transition to ethanol-blend fuels and afterwards. Additional training should be provided for inspectors that highlights the operation of the UST, as well as the changes needed to accommodate ethanol.
- ▲ More studies should be conducted on the compatibility UST tank systems with ethanol blends (especially with respect to the structural integrity of FRP tanks and flexible piping).
- ▲ The states should expand the *Proper Handling of Gasoline* campaign to include an education initiative for automobile and power equipment owners on the need for checking fuel compatibility specifications in their owner's manuals before using ethanol-blended fuels.

ENVIRONMENTAL IMPACTS

- ▲ The states should promote controlled field experiments to improve our understanding of the behavior of ethanol in the environment, help improve the accuracy of computer models that simulate the fate and transport of ethanol, and to inform the development of effective remediation techniques to cleanup neat ethanol and ethanol-blended gasoline releases.
- ▲ The states should promote an analysis of spill investigations from areas where ethanol-blended gasoline has been used to improve our understanding of cosolvency, the fate and transport of ethanol, and the effects of ethanol on the biodegradation of BTEX compounds at a field scale.
- ▲ Analyses of remedial actions and the performance of remedial technologies that have been employed are needed to understand the appropriateness, efficiency and cost of the various approaches.
- ▲ The states should promote field tests in the Northeast of those remediation technologies identified as promising in the literature review.
- ▲ The states should seek to establish federal/state/private partnerships to complete the significant amount of technical work needed over the next several years to prepare for the likely introduction of ethanol-blended gasoline.
- ▲ In order to better anticipate needs and develop appropriate responses, the states need to work with the ethanol industry and the federal government to better understand the entire life cycle of ethanol from production and usage in the region.
- ▲ From a water quality protection perspective, it would be prudent to limit ethanol content in RFG to the volume required by the current oxygen mandate (i.e., 5.7 percent) to minimize the effects of oxygen depletion and cosolvency, at least until the states are

HEALTH, ENVIRONMENTAL, AND ECONOMIC IMPACTS OF ADDING ETHANOL TO GASOLINE IN THE NORTHEAST

RECOMMENDATIONS continued

confident that its fate and transport characteristics are manageable at higher concentrations. However, the Northeast states recognize that this environmental concern must be balanced with competing air quality, economic and energy security interests in using higher concentrations of ethanol.

REGIONAL MULTI-MEDIA MONITORING AND ASSESSMENT PROGRAM

- ▲ The states should develop a regional baseline of methodologically consistent air and water quality data in order to track the impact of changes due to gasoline reformulation.
- ▲ State water quality agencies should include ethanol and terminal electron acceptors monitoring as a standard part of remedial investigations at petroleum release sites.
- ▲ The northeast states should employ standardized analytical methods for measuring ethanol in environmental water samples, including acceptable detection limits.
- ▲ The state air agencies should design a regional air toxics monitoring and data analysis strategy to establish a baseline and track potential changes in emissions of benzene, 1,3-butadiene, formaldehyde, acetaldehyde and POM as result of increased ethanol use.
- ▲ The states should conduct airshed modeling to evaluate the potential change in ambient concentrations of acetaldehyde and formaldehyde associated with a substitution of ethanol for M*t*BE.
- ▲ The state air agencies should design and deploy a monitoring network that will, at a minimum, measure ambient ethanol concentrations at likely worst case locations including near bulk storage and blending facilities, retail refueling stations, and ethanol production facilities, should any be built in the region.

VEHICLE EMISSION TESTING AND INVENTORIES

- ▲ A metastudy of existing emission test data should be conducted to determine whether statistically significant conclusions can be drawn regarding the emission characteristic of vehicles operating on ethanol.
- ▲ Additional vehicle emissions testing should be conducted if warranted based on the results of the metastudy.
- ▲ USEPA should develop appropriate inventory tools to avoid the use of the Complex Model for this purpose.

BIOMASS ETHANOL

- ▲ The Northeast states should further explore the potential benefits and costs associated with in-region production of ethanol made from biomass feedstock.
- ▲ The states should work collaboratively with the biomass ethanol industry and the USDOE in evaluating opportunities and constraints.
- ▲ This effort should be coordinated under the auspices of the existing Northeast Biomass Fuels Forum.

SUMMARY AND RECOMMENDATIONS ENDNOTES

[1] Relative Cancer Risk of Reformulated Gasoline and Conventional Gasoline Sold in the Northeast, NESCAUM, August 1998; Draft RFG/MTBE Issues and Options Papers – Phase I, NESCAUM, April 1999; RFG/MTBE Issues and Options Papers – Phase 2, NESCAUM, August 1999; and RFG/MTBE Findings and Recommendations, NESCAUM, August 1999. (www.nescaum.org)

[2] As measured by the “Complex Model” compliance tool described in the NESCAUM technical document.

[3] Hadder, G.R. (1999) Estimating Refining Impacts of Revised Oxygenate Requirements for Gasoline: Follow-Up Findings. Oak Ridge National Laboratory. *Draft* May 10, 1999.

[4] California Energy Commission (CEC) (1998) Supply and Cost of an Alternatives to MTBE in Gasoline October.

[5] M. Wang, Saricks, C., Santini, D. (1999) Effects of Fuel Ethanol Use on Fuel-Cycle Energy and Greenhouse Gas Emissions. Center for Transportation Research, Argonne National Laboratory. January.