STAFF REPORT

SUPPLY AND COST OF ALTERNATIVES TO MTBE IN GASOLINE

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CALIFORNIA
ENERGY
COMMISSION

Gray Davis, ***Governor***

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CALIFORNIA ENERGY COMMISSION

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*This report, **Supply and Cost Alternatives to MTBE in Gasoline**, was prepared in response to a legislative directive specified in Item 3360-001-0465 of the Supplemental Report of the 1997 Budget Act. This directive states that the Energy Commission should submit a report giving a detailed evaluation of alternative additives and compounds which could be used in lieu of Methyl Tertiary Butyl Ether (MTBE) in gasoline in California.*

Energy Commission staff worked with the California Air Resources Board to examine the environmental impacts of any potential increase in air pollution that might result from the use of an alternative oxygenate in gasoline. It should be noted, however, that this study does not include an assessment of the potential health impacts of exposure to MTBE or any other alternative oxygenates. In addition to the Energy Commission's report, the Governor and Legislature directed the Department of Health Services to determine the health impacts of MTBE in water and the California Air Resources Board to study the air quality and environmental impacts of discontinuing the use of MTBE.

ACKNOWLEDGEMENTS

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Table of Contents

Table of Contents
(Cont.)

Technical Appendices

Due to the size and number of appendices, they have been printed separately from the main body of the report. They are listed here for reference:

- Technical Documents, Purvin & Gertz, P300-98-013A
- Report on the Oxygenate Market: Current Production Capacity, Future Supply Prospects, and Cost Estimates, Energy Security Analysis, Inc., P300-98-013B
- Report on Tax Incentives for Ethanol, Energy Security Analaysis, Inc., P300-98-013C
- External CARB Gasoline Supply, Purvin & Gertz, P300-98-013D
- Adequacy Of Marine Infrastructure, Purvin & Gertz, P300-98-013E
- Impacts on External Markets, Purvin & Gertz, P300-98-013F
- Refinery Modeling Task 1: Specifying Scenarios And Methodology, MathPro, P300-98-013G
- Refinery Modeling, Task 2: Calibration of the Refinery Model, MathPro, P300-98-013H
- Refinery Modeling, Task 3: Supply Scenario Modeling Runs, MathPro, P300-98-013I
- Ethanol Blending Properties for Task 3 Modeling Work, MathPro, P300-98-013J
- Exhibits (P300-98-013K)

    A. Updated Informative Digest, Amendments to the California Cleaner-Burning Gasoline Regulations

    B. Oxygenate Information Sheets

    C. Federal Register Document, Change in Minimum Oxygen Content Requirement for Reformulated Gasoline

    D. Bill Summary and Status for the 105th Congress, H.R. 630

Executive Summary

Background

Since 1992, oxygenates have been required for use in California gasoline to help achieve compliance with both federal and state air quality regulations. Several oxygenates are available but Methyl Tertiary Butyl Ether (MTBE) has been the oxygenate of choice due to its compatible blending properties and lower cost. Small volumes of MTBE have actually been used in gasoline since the late 1970s by refiners as an octane enhancer to replace the lead being phased out of gasoline. Recently, however, MTBE has been detected in groundwater and at certain levels may pose a public health risk or render some drinking water unpalatable. The California Legislature held a hearing on May 12, 1997, to consider discontinuing the use of MTBE. Staff of the Energy Commission testified that an immediate replacement of MTBE would have a significant impact on California gasoline production, decreasing supply produced by California refiners by 15 to 40 percent. The probable temporary shortages and resulting price spikes would have a dramatic impact on California consumers.

Following the hearing, the Governor and Legislature directed the Energy Commission to examine the potential impacts of discontinuing MTBE on the production, price and supplies of gasoline in California. In conducting its comprehensive study, the Energy Commission analyzed a broad set of alternative oxygenates that could replace MTBE in gasoline. Item 3360-001-0465 in the ***Supplemental Report of the 1997 Budget Act*** states that the Energy Commission should submit a report to the Legislature that contains all of the following:

- *A detailed evaluation of alternative additives and compounds which could be used in lieu of Methyl Tertiary Butyl Ether (MTBE) in gasoline in California.*

- *An evaluation of the relative air quality and environmental benefits associated with each alternative additive or compound when compared to MTBE.*

- *An estimate of the potential costs or savings to the public in increases or decreases in retail gasoline prices for each alternative when compared to MTBE.*

- *An evaluation of the present and future availability of each alternative as compared to the availability of MTBE.*

- *An evaluation of the minimum time frames within which one or more alternatives could be substituted for MTBE without resulting in significant disruption of gasoline supply.*

Study Design

In order to fulfill the requirements of the Legislature's directive, the Energy Commission studied the following areas: the operation of the California refinery infrastructure under various scenarios simulated through computer models (refinery modeling), the supply and price of various levels of alternative oxygenates (oxygenates availability), the availability of the various components needed to make California's gasoline (import capability), and the ability of the existing distribution system to deal with various MTBE substitutes (state's infrastructure capability).

Refinery Modeling

This portion of the study used a computer model to look at the impacts of alternative oxygenates, different economic and regulatory conditions, and changing raw materials processing requirements under several cases. Each case was designed to simulate the statewide refinery operations to meet the projected daily average gasoline demand during the peak driving season (May through August). The existing California refinery infrastructure was then evaluated for its ability to respond to the various changes described in each case.

The analyses were performed by first running two base cases to determine baseline production costs for gasoline containing MTBE for the intermediate (three years) and long term (six years) timeframes. Next, cases were run with alternative oxygenates for both timeframes and compared to the appropriate base case to calculate an average gasoline price impact.

In addition to the alternative oxygenate cases, a case that reduces the amount of MTBE currently used in gasoline and another case that eliminates the use of all oxygenates were also examined. The first case is called "H.R. 630", in reference to the pending federal legislation that would allow California refiners to reduce the use of oxygenates in gasoline throughout California. This refinery modeling case was examined to determine how much MTBE could be removed from gasoline and what the cost impact to consumers would be.
The other case looked at the potential impact on supply and price of gasoline if discontinuance of MTBE was broadened to include all oxygenates. Since a great deal of concern has been expressed by some health and water officials over the use of any oxygenates in gasoline, an assessment of the possibility of producing all the gasoline for the state without the use of oxygenates was undertaken in order to quantify the cost impacts of no oxygenates in the intermediate and long term timeframes.

Oxygenates Availability

This portion of the study identifies each alternative oxygenate, its availability, and cost for the intermediate term and the long term. In addition the timeframe and cost to upgrade California's petroleum distribution facilities to make them compatible with each alternative oxygenate were determined.

The Energy Commission, in conjunction with the Air Resources Board, reviewed a number of different oxygenates to determine which ones were likely to be viable alternatives to MTBE. The oxygenates were assessed based on the following criteria: they are listed as a currently approved oxygenate by the U.S. Environmental Protection Agency, each possesses desirable blending characteristics, and each demonstrates potential adequate availability. Using these criteria, the Energy Commission decided to examine two alcohols, ethanol and TBA (tertiary butyl alcohol) and two ethers, ETBE (ethyl tertiary butyl ether) and TAME (tertiary amyl methyl ether), as potential replacements for MTBE.
All four alternative oxygenates were reviewed to determine if sufficient supplies could be produced to replace MTBE in gasoline. The study examined the global production capacities for the oxygenates currently being produced and examined facilities being constructed or in the planning stages to assess the potential availability of

these new supplies in the intermediate and long terms. Additionally, the costs to produce, transport and distribute the various oxygenates were examined and quantified.

Potential suppliers appear to have the production capacity and raw materials necessary to produce sufficient volumes of ethanol, ETBE and TBA under any of the various cases. TAME, however, does have a raw material limitation and was eliminated from consideration as a 100 percent replacement for MTBE. It is recognized, however, that most refiners could produce some volume of TAME through normal operations of their facility. Therefore, rather than eliminate it from consideration completely, staff examined TAME as part of a "mixed oxygenates" case. An economically optimal combination of ETBE, TBA and TAME was assessed to see if it would be less expensive than completely displacing MTBE with a single oxygenate.

Import Capability

This portion of the study estimated costs of importing various blending stocks and finished petroleum products to the California market to make up for shortfalls that may occur under any of the cases. This work required the following:

- Examining and categorizing more than 725 refineries worldwide to determine the volume of gasoline blending components each refinery could produce for use by California refineries.
- Estimating the cost of gasoline blending components supplied to California refineries.
- Determining the availability and cost of transporting gasoline blending components to California from several different regions of the world.

State's Infrastructure Capability

This work involved a detailed survey of California's marine terminal and distribution infrastructures to determine their ability to import various oxygenates and gasoline blending components as well as their ability to distribute gasoline that contained an oxygenate other than MTBE. Areas examined include:

- The ability of the California marine transportation infrastructure to handle substantial increases in imports of oxygenates and other gasoline components, and exports of refinery components that can no longer be blended into gasoline.
- The ability to transport gasoline containing different oxygenates through the pipeline distribution system.
- The ability of terminals to blend certain oxygenates into gasoline.
- The ability to transport and off-load substantial volumes of ethanol via railroad cars and marine tankers.

Results Of Study

This study examines the impact of discontinuing the use of MTBE on supply and price of gasoline to California consumers. The findings of this study indicate that the cost impacts for consumers are directly related to the period of time permitted for phasing out MTBE:

- If the use of MTBE were discontinued immediately, the consequences would be dire for consumers and catastrophic for California's economy.

- Allowing three years to transition to an alternative oxygenate would be enough time for refiners and oxygenate producers to take the necessary actions to meet demand. Depending upon the alternative oxygenates used, the change in average cost of gasoline could range from a decrease of 0.2 cents per gallon to an increase of 6.7 cents per gallon. Consumers could see either a savings of $30 million per year or an additional expense of $991 million per year.

- If six years is allowed to phase out the use of MTBE, the change in average cost of gasoline could range from a decrease of 0.4 cents per gallon to an increase of 2.5 cents per gallon, depending upon the alternative oxygenate used. Consumers could see either a savings of $63 million per year or an additional expense of $392 million per year.

If the scope of replacing MTBE were to be broadened to include the elimination of all oxygenates from gasoline, the cost impact for consumers would be the greatest, regardless of the length of time allowed for the transition, ranging up to 8.8 cents per gallon in the intermediate term and 3.7 cents per gallon in the long term. On an annual basis these costs would amount to $1.3 billion and $580 million, respectively.

Cost, Availability and Timeframe

The results of the study indicate a substantial variation in gasoline prices under the timeframes necessary to modify refineries and increase production of alternative oxygenates under various cases. The average cost increase is a measure of how much more expensive California's gasoline production would be compared to the production of gasoline with MTBE. This study assumes that any change in average cost would be passed through directly to the consumer. Therefore, the retail price of gasoline would reflect this change. It should be noted that retail prices reflect not only production costs but also other market conditions which will influence the final price. If regulations imposed are so stringent that California refineries can no longer supply all or substantial amounts of the products the state requires, then the impact on retail price could be even greater than just the average cost increase. Additional information concerning costs, both average and marginal, is provided in Appendix I (Refinery Modeling, Task 3, Supply Scenario Modeling Runs).

The Energy Commission analysis considers three timeframes: near term (immediate), intermediate term (three years), which allows for some modification and infrastructure changes to accommodate a different oxygenate, and long term (six years), which allows for major refinery modifications to accommodate a different oxygenate. Results were evaluated based on the availability of the oxygenates under consideration and gasoline blending components needed to meet demand, the transportation and necessary infrastructure modifications, and the availability of shipping, trucking and pipelines to handle the distribution under each timeframe.

Near Term. In the near term case, the study shows that an immediate discontinuation of the use of MTBE could produce significant gasoline and diesel supply shortfalls and a rapid increase in prices. MTBE not only oxygenates the gasoline but also helps to dilute and offset the undesirable properties of other gasoline components. Therefore, although MTBE itself accounts for only 11 percent of the total volume of gasoline, its absence would mean that refiners would have to replace these other components as well, resulting in an anticipated 15 to 40 percent shortfall.

In April 1996, a fire at a refinery in northern California resulted in a temporary shortfall in gasoline production that was substantially less than 15 percent. This shortfall resulted in prices rising by about 30 cents per gallon. If prices were to rise proportionally during an immediate discontinuance of the use of MTBE, the results would be drastic for consumers and catastrophic for California's economy.

Refiners would need to acquire adequate replacement oxygenates and imports, but they would have insufficient time for a smooth, nondisruptive transition. Renegotiating contractual arrangements, resolving production capacity constraints, and overcoming inadequate transportation services are just a few of the serious problems suppliers would face in attempting to meet the dramatic change in demand.

Each alternative oxygenate has limiting factors that would prevent an adequate supply to meet California's needs in the near term. Even if industry is able to overcome these primary limiting factors and introduce a replacement oxygenate quickly, the price would still be very steep because demand would exceed the readily available supply.

ETBE, TBA and TAME are not currently produced in volumes adequate to meet California's needs. Although the distribution system requires little, if any, modification to handle any of these alternative oxygenates, modifications would have to be undertaken at existing MTBE plants to convert them to ETBE or TBA production. This type of work would require between 12 and 24 months for completion before necessary volumes could be available for use in California. TAME, which is a by-product of refinery operations, is expected to be limited to modest production volumes at refineries.

In the case of ethanol, the United States produces about 80,000 barrels per day of ethanol to meet current demand for all uses. California currently produces approximately 400 barrels per day. In the near term case, California would suddenly require the majority of ethanol that is being supplied to other users around the country. In order to secure the necessary volumes, California refiners will have to purchase the ethanol by bidding above and beyond what present users pay. This action would cause the price of ethanol to increase significantly above its current market price.

Even if enough of the current ethanol production in the United States were to be diverted for California's projected needs, several other factors would impede the immediate use of ethanol without considerable disruption to California's gasoline market. The main limiting factor is the lack of adequate blending equipment at the distribution terminals. It would require between 18 and 24 months to complete necessary modifications to storage tanks, unloading facilities and blending equipment.

If H.R. 630 were to pass and allow California refiners to reduce the amount of oxygenates currently used in gasoline, this additional flexibility would certainly allow refiners to reduce the amount of oxygenates used in the intermediate and long term time periods, but it is doubtful that this legislation will appreciably impact the dire consequences of an immediate discontinuance of

TABLE 1 Average Cost Change Cents Per Gallon		
	Intermediate Term	**Long Term**
Ethanol	6.1 to 6.7	1.9 to 2.5
ETBE	2.4 to 2.5	0
TBA	0.5 to 1.4	0.3 to 1.0
Mixed Oxygenates	-0.2 to 0.2	-0.3 to -0.4
HR 630	-0.2 to -0.8	-0.3 to -1.5
No Oxygenates	4.3 to 8.8	0.9 to 3.7
One Pound Waiver	4.0 to 5.4	-0.8 to 1.0

the use of MTBE in the near term. Refiners would be desperately trying to acquire as much alternative oxygenates as possible, struggling to minimize supply disruptions, rather than attempting to economize on refinery costs as would be the case in the longer time periods.

Eliminating the use of all oxygenates in gasoline in the near term would exacerbate an already dire situation. Prohibiting refiners from acquiring alternative oxygenates would worsen an already desperate setting whereby refiners would be scrambling to acquire as much additional gasoline components and alternatives to oxygenates as possible in order to provide as much gasoline as they could to compensate for the discontinuance of all oxygenates.

Intermediate Term (3 years). In the intermediate term case, the supply impacts would be less dramatic but costly. The change in average cost of gasoline could range from a decrease of 0.2 cents per gallon to an increase of 6.7 cents per gallon, depending upon the oxygenate.

The study assumes that in 2002, California's gasoline demand will be about 965,000 barrels per day (14.8 billion gallons per year). California gasoline demand can be met by producing blending materials at California refineries, importing additional blending materials if needed, and importing the appropriate oxygenate. The results of the intermediate term case suggest that ethanol, ETBE and TBA will be available in sufficient volumes to meet demand but at market prices higher than in the long term case. TAME will not be available in sufficient volumes to meet California's needs by itself. Listed below are the results for the intermediate term (see Table 1).

- **Ethanol**. Beginning in 2002, California refineries would require as much as 75,000 barrels per day of ethanol and up to 142,000 barrels per day of additional gasoline imports to meet demand. The average cost increase is expected to be in the range of 6.1 to 6.7 cents per gallon or $902 to $991 million per year.

- **ETBE**. Beginning in 2002, California refineries would require as much as 129,000 barrels per day of ETBE to meet demand. No additional gasoline imports would be required. The average cost increase is expected to be about 2.5 cents per gallon or $370 million per year.

- **TBA**. Beginning in 2002, California refineries would require as much as 89,000 barrels per day of TBA and up to

22,000 barrels per day of additional gasoline imports to meet demand. The average cost increase is expected to be in the range of 0.5 to 1.4 cents per gallon or $74 to $207 million per year.

- **Mixed Oxygenates**. Beginning in 2002, California refineries would require as much as 101,000 barrels per day of an optimal combination of assorted oxygenates (excluding MTBE) to meet demand. No additional gasoline imports would be required. The change in average cost is expected to be range from a decrease of 0.2 cents per gallon to an increase of 0.2 cents per gallon. Consumers could see either a savings of $30 million per year or an additional expense of $30 million per year.

- **H.R. 630.** Beginning in 2002, California refineries could reduce their use of MTBE by over 30 percent if federal legislation were to allow them to make gasoline with less than the current minimum oxygen content. As much as 20,000 barrels per day of additional gasoline component imports would be required to meet demand. This additional flexibility allows the average cost for gasoline to consumers to decrease in the range of 0.2 to 0.8 cents per gallon or $30 to $118 million per year in savings.

- **No Oxygenates Case.** Beginning in 2002, California refiners would require as much as 355,000 barrels per day of additional gasoline component imports to meet demand without the use of any oxygenates. The average cost increase is expected to be in the range of 4.3 to 8.8 cents per gallon or $636 million to $1.3 billion per year. This case would require the passage of H.R. 630.

Long Term (six years). The long term case provides the least cost option by allowing adequate time for the oxygenates market to achieve a new supply and demand balance at a lower price. In addition, refiners would have sufficient time to modify their equipment where appropriate. In response to achieving a normal supply and demand balance, prices would moderate to an average cost difference ranging from a decrease of 0.4 cents per gallon to an increase of 2.5 cents per gallon.

Over the long term, the availability of alternative oxygenates will increase as more time is allowed to increase production capabilities for ethanol, ETBE and TBA. Within six years, supplies of all three alternatives could be comparable to current MTBE availability. TAME, which is a by-product of refinery operations, will not be available in sufficient volumes to meet California's needs by itself.

The study assumes that in 2005, California's gasoline demand will be about 1,022,000 barrels per day (15.7 billion gallons per year). California gasoline demand can be met by producing blending materials at California refineries, importing additional blending materials if needed, and importing the appropriate oxygenate. Listed below are the results for the long term (see Table 1).

- **Ethanol**. Beginning in 2005, California refineries would require as much as 79,000 barrels per day of ethanol and up to 113,000 barrels per day of additional gasoline imports to meet demand. The average cost increase is expected to be in the range of 1.9 to 2.5 cents per gallon or $298 to $392 million per year.

- **ETBE**. Beginning in 2005, California refineries would require as much as

137,000 barrels per day of ETBE to meet demand. No additional gasoline imports would be required. The average cost increase per gallon is expected to be negligible.

- **TBA**. Beginning in 2005, California refineries would require as much as 104,000 barrels per day of TBA and 18,000 barrels per day of additional gasoline imports to meet demand. The average cost increase is expected to be in the range of 0.3 to 1.0 cents per gallon or $47 to $157 million per year.

- **Mixed Oxygenates**. Beginning in 2005, California refineries would require as much as 126,000 barrels per day of an optimal combination of assorted oxygenates to meet demand. No additional gasoline imports would be required. The average cost decrease is expected to be in the range of 0.3 to 0.4 cents per gallon or a savings of $47 to $63 million per year.

- **H.R. 630.** Beginning in 2005, California refineries could reduce their use of MTBE by over 20 percent if federal legislation were to allow them to make gasoline with less than the current minimum oxygen content. As much as 10,000 barrels per day of additional gasoline component imports would be required to meet demand. This additional flexibility allows the average cost for gasoline to consumers to decrease in the range of 0.3 to 1.5 cents per gallon or $47 to $235 million per year in savings.
- **No Oxygenates Case.** Beginning in 2005, California refiners would require as much as 170,000 barrels per day of additional gasoline component imports to meet demand without the use of any oxygenates. The average cost increase is expected to be in the range of 0.9 to 3.7 cents per gallon or $141 to $580 million per year. This case would require passage of H.R. 630.

Air Quality and Environmental Impacts

Energy Commission staff worked with the California Air Resources Board (CARB) to examine the potential increase in pollutant emissions that might result from the use of an alternative oxygenate in gasoline. It should be noted, however, that this study does not include an assessment of the potential health impacts of exposure to MTBE or any other alternative oxygenates in gasoline.

The use of alternative oxygenates in reformulated gasoline does not result in an increase in air pollution as long as the gasoline recipe used by refiners passes the Predictive Model and none of the various fuel qualities exceed the maximum levels set by CARB. ETBE, TBA and TAME are each comparable in air quality impacts to MTBE. Ethanol, at the current 7.0 pound maximum volatility requirement, is also comparable. However, current state law exempts gasoline containing 10 percent ethanol from CARB’s limit on volatility unless CARB finds that such gasoline, without volatility control, increases the ozone-forming potential of vehicular emissions.

At this time, the preliminary results of a vehicle test study performed by CARB show that gasoline blends of 10 percent ethanol and a maximum volatility of 8.0 pounds would cause major increases in hydrocarbon emissions, the ozone-forming potential of those emissions, and benzene emissions--all mostly due to excess evaporative emissions.

Higher exhaust emissions of nitrogen oxides would also be expected.

The staff of CARB will present these results and other information to its Board. If the Board makes a finding of greater ozone-forming potential for emissions from 10 percent gasoline without volatility control, there will be no exemption from the volatility limit. Since the final adoption has not occurred, the Energy Commission has examined a case of a one pound increase in volatility over the 7.0 psi limit to see what the impact could be on the production costs of reformulated gasoline for California refineries.

With an allowance for refiners to make gasoline with a higher volatility, the refinery modeling results indicate that the feasibility of this case hinges on which variation of the Predictive Model is used by refiners. In average mode, refiners would be forced to decrease the amounts of sulfur, aromatics and olefins to levels much lower than today's gasoline in order to get a recipe of gasoline to pass the Predictive Model. This practice would necessitate importing over 50 percent of our gasoline needs, significantly increasing the price of gasoline for consumers.

Use of the average mode of the Predictive Model leads to an infeasible case in both the intermediate and long term timeframes.

If refiners used the flat limit mode of the Predictive Model, complying gasoline can be produced at an average cost increase of 5.4 cents per gallon in the intermediate term and 1.0 cents per gallon in the long term. These additional costs would amount to nearly $800 million in the intermediate term and $157 million in the long term. As much as 103,000 barrels per day of ethanol and 50,000 barrels per day of additional gasoline imports would be required to meet demand.

Another interpretation of the regulatory language associated with the one pound volatility waiver is a formulation of reformulated gasoline that is similar to the flat limit recipe, except for a higher volatility of 7.8 pounds and an oxygen content of 3.5 weight percent. Refinery modeling results indicate that this blend of gasoline can be produced at an average cost increase of 4.0 cents per gallon in the intermediate term. In the long term, this blend of gasoline can be produced at an average cost decrease of 0.8 cents per gallon.

As to water quality, ongoing testing indicates that some other oxygenates have been detected in some surface and ground water sources. Similar to MTBE, compounds such as ethanol, ETBE, TAME and TBA are able to mix with water, are difficult to remove from contaminated water and cause water to taste and smell unpleasant even at very small concentrations. Additional results can be found in the study performed by the University of California.

Uncertainty

Recent studies indicate that ETBE, TBA and TAME possess unpleasant characteristics similar to MTBE that could lead to odor and taste problems in drinking water at very low concentrations. The two most preferred alternatives for phasing out MTBE, according to the UC study, would be either ethanol or the use of no oxygenates. The findings in this study show that use of no oxygenates or ethanol to completely displace MTBE would require substantial increases in imports of key gasoline blending components such as alkylate. Concerns have been raised that these large volumes of alkylate and other gasoline components would either be much more expensive or unavailable altogether.

Additional refinery modeling work was undertaken to determine the impacts on average cost of gasoline if these imports were unavailable over the long term. The results of these new cases indicate that eliminating the need to import additional alkylate by building additional refinery capacity in California would add 0.2 cents per gallon to the ethanol cases and 0.6 cents per gallon to the no oxygenate cases. Although these cost increases are modest in the long term, there is concern that if MTBE is phased out over a period of time that is insufficient to allow refiners to make necessary modifications, there will be an undetermined level of risk associated with imports of large volumes of alkylates. The potential risk in the intermediate term associated with inadequate availability of marine vessels, higher costs of imports and difficulty in obtaining sufficient volumes of alkylate could lead to higher costs than indicated in this study under the ethanol and no oxygenate cases.

Key Findings

Introduction

This chapter summarizes the key findings from this study. Detailed information for each case is provided in the technical appendices. To adequately respond to questions raised by the Legislature, the study was conducted for three separate time periods: near term, intermediate term and long term.

Near Term. This case examines the impacts of an immediate replacement of MTBE in California only. Since this case would take place immediately within California, it is assumed that the rest of the country would not have had a chance to follow suit. The word "immediately" should be interpreted to mean that industry is given no phase-in time to prepare and must deal with the existing hardware, regulations, terminals and fuel distribution system. The near term analysis was performed qualitatively because the dramatic results of an immediate discontinuance of the use of MTBE under current regulations would be so severe that laying out any particular outcome would imply an accuracy of prediction that is not possible.

Intermediate Term. This case examines the impact of phasing out MTBE over a three year period, which allows for some modification and infrastructure changes to accommodate a different oxygenate.

Long Term. This case examines the impact of phasing out MTBE over a six year period, which allows for major refinery modifications to accommodate a different oxygenate.

The intermediate term and long term analyses were done quantitatively and performed under the assumptions that MTBE is phased out and, unless otherwise specified in a case run, all state and federal air quality regulations and tax credits remain in place.

Regardless of timing, the discontinuance of the use of MTBE would require refiners and gasoline blenders to use a replacement oxygenate. Under California Air Resources Board (CARB) regulations, any gasoline sold in California must meet strict air quality specifications which normally includes the use of oxygenates to ensure compliance with reformulated gasoline specifications. By federal law, oxygenates must be used in all of California's federal non-attainment areas. This requires about two-thirds of the quantity of gasoline sold in California to have a minimum oxygen content of 1.8 weight percent all year.

Oxygenates Chosen For Study

The Energy Commission, in conjunction with CARB, reviewed a number of different oxygenates to determine which ones were likely to be viable alternatives to MTBE. The oxygenates were assessed based on the following criteria: they were listed as a currently approved oxygenate by the U.S. Environmental Protection Agency, each possessed desirable blending characteristics, and each demonstrated potential adequate availability. Using these criteria, the Energy Commission decided to examine two alcohols; ethanol and TBA (tertiary butyl alcohol) and two ethers; ETBE (ethyl tertiary butyl ether) and TAME (tertiary amyl methyl ether), as potential replacements for MTBE.

Methanol was found to be unacceptable as a viable alternative to MTBE because its use would increase the vapor pressure of gasoline to a level that would violate the volatility standard of California's reformulated gasoline specifications. Ethanol also increases the vapor pressure of gasoline, but the effect is lower than with methanol and can be overcome (with difficulty) by using different blending strategies. Methanol, as an additive, has an additional problem in terms of its solubility with water. If the blend of gasoline with methanol comes in contact with water, methanol separates from the gasoline, rendering the gasoline out of compliance.

The alternative oxygenates were reviewed to determine if their potential production capacity was limited by raw materials or feedstocks. Although ethanol, ETBE and TBA appear to have adequate feedstocks under any of the various cases, TAME does have a raw material limitation. As a result, TAME was eliminated from consideration as a 100 percent replacement for MTBE. We recognize, however, that most refiners could produce some volume of TAME through normal operations of their facility. Therefore, rather than eliminate it from consideration completely, we examined TAME as part of a "mixed oxygenates" case which looks at an economically optimal combination of ETBE, TBA and TAME to see if it is more economically viable.

A great deal of attention has been placed on the pending federal legislation (H.R. 630) that would permit California refiners to blend gasoline with oxygen content less than 1.8 weight percent. Federal law currently requires gasoline sold in all federal ozone nonattainment areas of California (applies to roughly two-thirds of the fuel sold in the state) to contain at least 1.8 weight percent oxygen. Even though CARB regulations allow refiners the flexibility to produce gasoline blends containing oxygen at levels below 1.8 weight percent, only a few of them are currently able to reduce their oxygenate use (in the San Francisco Bay Area and limited areas in northern California). If H.R. 630 becomes law, refiners would be allowed to exercise this additional flexibility throughout the entire state. Additional flexibility is expected to translate into lower costs, primarily because the cost of MTBE is greater than the cost of other gasoline components that could be used in its place. It would be used as an octane booster, rather than a required response to a mandated minimum oxygen content.

Although the primary focus of this study is to assess the impact on supply and price of gasoline if MTBE were to be phased out, the Energy Commission recognizes that the alternative oxygenates studied are not without controversy. As a result, the Energy Commission examined the impact on supply and price of gasoline in the event that all oxygenates were discontinued.

Model Methodology

The California reformulated gasoline regulations contain a compliance option which a producer or importer of gasoline may use called the California Predictive Model. The Predictive Model is a computer program which consists of mathematical equations which estimate changes in air pollution from exhaust emissions of vehicles.

The Predictive Model can be operated in two different modes: "averaging" or "flat limit." A refiner using the averaging version of the Predictive Model submits a gasoline recipe to CARB that demonstrates no increase in air pollution compared to the standard average gasoline formula. The refiner is able to determine if the gasoline recipe complies with CARB regulations by first entering the gasoline properties into the Predictive Model computer program. If the calculated exhaust emissions are equal to or better than the standard average gasoline formula, the computer model results will indicate a "pass". If the emissions are greater, the results will indicate a "fail."

The concept is similar for the flat limit version of the Predictive Model. The refiner will first check with the computer program to make sure their gasoline recipe complies with California regulations before submitting it to CARB.

The fuel properties under the average version of the Predictive Model are more stringent than the flat limit version because the refiner is allowed to produce a batch of gasoline with a fuel property greater than the one submitted in their average gasoline recipe. This is acceptable as long as the refiner compensates by later producing a batch of gasoline of equivalent size whose fuel property is lower than their average recipe.

On the other hand, under the flat limit version of the Predictive Model the refiner is never allowed to produce a gasoline with a fuel property greater than the one submitted to CARB. If the gasoline is sampled and results of the fuel analysis indicate a measurement greater than any of the properties submitted in the flat limit recipe, this batch of gasoline will be in violation and the company will be subject to a fine. In other words, the actual fuel properties of the gasoline being produced by a refiner using the flat limit version of the Predictive Model are lower than the recipe submitted to CARB. The "margin of safety" gives refiners greater assurance that the variability normally associated with equipment used to test properties of gasoline will be accounted for, avoiding a costly fine.

For purposes of the Energy Commission analysis, the refinery modeling was conducted using both versions of the Predictive Model (average and flat limit) in recognition that refiners are currently using one or the other to produce complying gasoline.

Distribution Infrastructure Improvements

An assessment of California's distribution infrastructure was undertaken to determine what level of capital improvements would be necessary before gasoline containing alternative oxygenates could be dispensed throughout the entire system. The findings indicate that costs would only be incurred for the cases involving ethanol. Currently, the distribution system is able to accommodate gasoline containing either ETBE, TBA or TAME without having to undergo modifications.

The distribution infrastructure consists of a system of pipelines, storage tanks, railroad spurs, and tanker truck loading equipment. Most refineries in California have access to pipelines that are capable of transporting a variety of refined petroleum products, namely gasoline, diesel and jet fuel. The pipelines are connected to terminals located throughout the state and permit refiners to transport their gasoline and other fuels to areas of the state at costs that are much less than transportation by rail or tanker truck. These terminals usually consist of several storage tanks and equipment used to load tanker trucks before they haul the gasoline to a service station. A number of these terminals are also able to receive shipments by rail. Some of the terminals located near water are also able to receive shipments from marine vessels.

Except for ethanol, gasoline containing MTBE or any other oxygenate does not require any special handling before being transported by truck to the service station. Pipelines and most storage tanks usually contain small amounts of water that accumulate over time as a result of condensation or minor contamination of petroleum products. The presence of this water is generally not a problem for gasoline because the two compounds do not have a tendency to mix together. Refiners are reluctant to ship gasoline containing ethanol through the pipeline distribution system because ethanol has an affinity for water.

This attraction and ability to blend with water means that ethanol in the gasoline would have a tendency to pick up some water and other contaminants suspended in the water. In order to prevent a degradation of fuel quality, ethanol would not be mixed with the gasoline until the fuel is loaded into the tanker truck. This handling procedure necessitates that the ethanol be stored in segregated storage tanks and special gasoline blending equipment be installed at the terminals. The special blending equipment would permit ethanol and gasoline to be loaded into the tanker truck either simultaneously or in sequence. Currently, the majority of terminals do not possess this capability.

Most of the terminals in California would require some degree of modification before gasoline containing ethanol could be dispensed. These modifications would involve work that would enable the operators of the terminal to receive, store and blend ethanol. The costs associated with these modifications are estimated to total approximately $60 million and require as long as two years to complete. These additional capital expenditures would contribute about 0.1 cents per gallon to the average cost of producing gasoline containing ethanol.

Terminal operators would have to make certain modifications to their facilities so that they would be able to receive shipments of ethanol by either rail or tanker truck, since the ethanol will not be shipped separately through the pipeline. Modifications to upgrade existing rail facilities and construct new facilities are estimated to cost nearly $10 million and take up to two years to complete. Some terminal facilities do not have access to rail and are expected to receive ethanol shipments by tanker truck. Modifications to upgrade existing facilities and construct new truck unloading facilities are estimated to cost less than $9 million and require up to two years to complete.

Ethanol would have to be stored in separate tanks prior to being blended into the gasoline. To allow for the segregation of ethanol, terminal operators would employ two different strategies. One approach would be to store ethanol in a tank that was once used for some type of petroleum product. These modifications are estimated to cost less than $4 million and require up to a year to complete. The other strategy would be to construct brand new storage tanks at an expense estimated to be over $12 million. This work would require up to two years to complete.

The single greatest cost element involves the installation of blending equipment that would permit blending of ethanol into gasoline as the tanker trucks are being loaded. These costs are estimated to be less than $25 million and would involve modifications to nearly 150 truck loading lanes. This work would require up to two years to complete. No new truck loading lanes are expected to be constructed as a result of blending gasoline with ethanol at the terminals.

Near Term Analysis

For the purposes of this analysis, it is assumed that:

- The California Legislature immediately removes MTBE from use in any gasoline sold for use in the state, but it is still used in the rest of the country.

- Any EPA-approved oxygenate other than MTBE could be used. Hence, ethanol, TAME ETBE and TBA all would be available as blendstocks from a legal and regulatory point of view.

- Refiners would be required to produce the new gasoline immediately. However, refiners, marketers and service station owners would still be permitted to sell existing inventories of gasoline containing MTBE until such inventories are depleted.

- New production of gasoline will flush out any remaining amounts of MTBE from the distribution system.

- There would not be enough time to allow refinery modifications such as major equipment changes or minor debottlenecking, or any modifications to the distribution infrastructure that could be required for the use of certain types of oxygenates.

- There would not be enough time to allow MTBE facilities to be converted to the production of another oxygenate. The only exception is for facilities that currently have the option to produce either MTBE or ETBE.

The Energy Commission provided testimony in May 1997 that an immediate discontinuance of the use of MTBE could cause a shortfall of 15-40 percent of gasoline supplies in California. The Energy Commission's current analysis supports these initial findings.

Since the presence of MTBE helps to dilute some of the less desirable properties of gasoline (for example, benzene), removing MTBE from gasoline (which is 11 percent by volume) would leave refiners with a combination of gasoline blending components that would result in gasoline that does not comply with California regulations. Refiners would have to take additional actions if the use of MTBE were not permitted.

One of these actions would involve changing the combination of gasoline blending components mixed to make gasoline. Certain blending components contain high levels of undesirable properties and would have to be used in other petroleum fuels or exported. In addition, some blending components are also low in octane, forcing refiners to seek higher octane substitutes from outside California to ensure all grades of gasoline can be produced.

As a direct result, the loss of California gasoline production capability would exceed the 11 percent volume represented by the absence of MTBE alone. The immediate absence of MTBE would affect some refineries more than others, but the end result is a total decline in production capability as high as 40 percent.

Disallowing the use of MTBE in gasoline in the near term would be so disruptive that resulting market conditions would be far outside any experience. Since even a modest shortfall in available fuel triggers substantial price increases, the major shortfall that may develop from an immediate halt in the use of MTBE is expected to result in the most severe price disruptions that have ever been experienced in California's gasoline market. Prices would have to rise to the level that enough demand is discouraged so that remaining demand is balanced with available supply. The upward price movements would be so large as to overcome any conceivable economic barrier to any action that could extend supplies of fuel. Supplies would be limited by physical and regulatory considerations.

The disruptions arising from severe shortages of fuels most probably would lead to suspension of all environmentally-driven fuel quality programs. While this outcome violates one of the case assumptions, it should be noted that over some period of time, probably measured at least in months, this would be the inevitable outcome of an immediate discontinuance of the use of MTBE. It is believed that under existing legal authority both the state and federal programs could be suspended. Once programs are suspended the supply and demand balance in California could be restored in fairly short order using production and imports of conventional gasoline (MTBE-free gasoline that can be legally sold in the U.S.).

Following are the results of the near term analysis for each of the alternative oxygenate cases studied:

Ethanol

Discontinuing the use of MTBE removes 110,000 barrels per day of volume from California gasoline, replacing it with about 50,000 barrels per day of ethanol. However, because MTBE is a desirable blending component that is used in part as a diluent, acceptable gasoline components used in conjunction with MTBE would now become undesirable when used in conjunction with ethanol. These components which need to be replaced could amount to as much as an additional 100,000 barrels per day. This would require importing over 150,000 barrels per day of acceptable blending components or finished gasoline to meet California's demand.

The United States produces about 80,000 barrels per day of ethanol to meet current demand for all uses. In addition, another 30,000 barrels per day of spare production capacity is idle. California currently produces approximately 400 barrels per day of ethanol. With an immediate need for a replacement for MTBE, California would suddenly require the majority of ethanol that is being supplied to other users around the country. In order to secure the necessary volumes, California refiners will have to purchase the ethanol by bidding above and beyond what present users pay. This action would create significant pressures, increasing the price of ethanol well above its current market price.

The ethanol market is not entirely flexible, however. Many ethanol producers have contractual obligations to supply their traditional customers and some of the ethanol cannot be immediately bid away. In addition, the long-standing ethanol market in the midwest includes state tax incentives on top of the federal subsidy. Many ethanol producers may view the potentially short-term selling opportunity in California as a risky business decision and not enter this market. This will reduce the amount of ethanol immediately available to California.

In the near term, California refiners have few alternatives to buying ethanol. Suppliers have no obligation to sell, and the price could rise rapidly. The structure of the ethanol industry may reinforce this possibility, as the top five producers in the country control nearly 65 percent of production capacity. One company alone controls nearly half of all U.S. ethanol production. With the concentration of ethanol production in the hands of relatively few suppliers, consumers may further be harmed by the lack of competitive market forces.

In addition, transportation costs by rail from the Midwest, where the majority of ethanol production is centered, will add approximately 15 cents per gallon to the price of ethanol. Ethanol has to be brought over by rail since there are no pipelines connecting California to the Midwest. Due to the cost involved, it is unlikely that ethanol would be transported by rail to the Gulf and from there transported by ship to California.

Outside of the United States, spare ethanol production capacity is extremely limited. Brazil dominates the industry and produces about 250,000 barrels per day. About 85% of this ethanol cannot be exported, either because of law or because it is currently committed for use within the country. All gasoline in Brazil must contain a mixture of 24% ethanol and many cars run on 100% ethanol. Brazil currently has higher than normal inventories of ethanol which could be drawn down to more normal levels and sold to California (equaling about 9,000 barrels per day). Added to the 30,000 barrels per day of temporary surplus production in Brazil, this brings the total ethanol available for export to California to about 39,000 barrels per day.

Assuming a demand in California of 50,000 barrels per day of ethanol, Brazil could supply part of California's requirements for close to nine months. Brazilian ethanol imported into the United States, however, is subject to a 54 cent/gallon import duty in addition to transportation charges. While it is possible that enough ethanol can be imported to meet California's requirements in the near term, it will only be available to California at very high prices.

Currently, ethanol is available for about $1.02 per gallon on the Brazilian spot market. Charges for freight, port and insurance would add $.23 per gallon to that price. The U.S. tariff of $.54 per gallon would bring the total price to about $1.79 per gallon. Compared to the current price of domestically produced ethanol, which is about 70 cents per gallon less, this is clearly an expensive alternative. Once the surplus ethanol market in Brazil returns to a normal balance, it will become even more expensive.

ETBE

Currently, the United States produces only a small quantity of ETBE but has about 51,000 barrels per day of ETBE capacity. California would require about 115,000 barrels per day. ETBE production would be complicated by the fact that each gallon of ETBE requires a feedstock of 43 percent ethanol. Further, conversion of large scale MTBE production capacity cannot be completed overnight, nor without considerable cost in many cases. ETBE manufacturing would probably be centered around the U.S. Gulf Coast, where most U.S. ether facilities are located.

Ethanol would need to be transported from the Midwestern producer states to the Gulf Coast for ETBE production and then finished ETBE would be shipped to California. Hence, wide scale ETBE production to supply California would involve many of the same problems discussed above for ethanol. Suddenly ether producers would need to secure large quantities of ethanol currently being supplied to other end users. However, ETBE has very good blending characteristics and requires very few refinery modifications to accommodate its use.

Another consideration is that since ETBE production will involve taking over MTBE production facilities, MTBE production for the rest of the marketplace will be "crowded out." Gasoline blenders around the country will have fewer supplies, and may compete with ethanol or ETBE, further bidding up the price of oxygenates in general.

TBA

TBA is in a similar position to ETBE. Currently, the United States production capacity for TBA is about 35,000 barrels per day. California would require about 80,000 barrels per day. TBA production is very limited (approximately 60,000 barrels per day of capacity around the world), with one company controlling most of this capacity. TBA production is far short of the volume required by California to replace MTBE, and would require many California blenders to bid for TBA from at most one or two suppliers. This situation presents a likelihood of higher prices for TBA.

Mixed Oxygenates

Currently, the United States has the capacity to produce about 23,000 barrels per day of TAME. California would require about 112,000 barrels per day. TAME is presently produced in fairly small volumes in scattered locations around the U.S. and in some foreign countries.

Even at full production capacity (approximately 47,000 barrels per day worldwide), there would not be enough TAME to supply the California market's full oxygenate requirement. California blenders would have to bid for this very limited supply generally from refiners with TAME units at their refineries. These refiners might be reluctant to supply the California market, as they would then need to find replacement oxygenates themselves for gasoline blending previously accomplished with TAME.

Impacts of H.R. 630

An immediate halt to the use of MTBE would have a drastic impact on the price of gasoline for consumers. If refiners could use less than the minimum oxygen content that is required by federal law, it is possible that these consequences could be marginally improved. Since H.R. 630 or some similar federal legislation has not been passed at this time, it is very unlikely to expect such federal legislative action to coincide with an immediate halt to the use of MTBE in California. For this reason, further analysis of the potential merits of H.R. 630 in the near term were not examined.

No Oxygenates Case

If MTBE were to be discontinued immediately, refiners would at least be left with the option of trying to acquire some additional volumes of alternative oxygenates as quickly as possible to try and recover some portion of their reduced gasoline production. If California were to broaden the scope to include discontinuing all oxygenates, the drastic impacts on supply and price of gasoline for California consumers would be even more extreme.

Intermediate Term Analysis (Three Years)

Two to three years is assumed to be sufficient to allow the markets for alternative oxygenates to develop and attain a new level of supply and demand balance. Refiners would not have time to undergo major equipment modifications, but would still have time to modify certain process operations that would improve their ability to meet product demand without the use of MTBE.

Staff assumed that construction permits would be obtained without significant delays. Based on surveys, marketers throughout the distribution infrastructure state that, under this scenario, they have sufficient time to modify any terminals, truck loading racks and marine facilities to support the use of another oxygenate.

In the intermediate term, demand for gasoline in California is expected to be 965,000 barrels per day. As shown in Tables 2A and 2B, the amount of materials produced at the refinery or imported will vary depending upon the oxygenate. Table 3 displays the resulting changes in cost. Below is a discussion of each oxygenate case.

Ethanol

Ethanol is the most expensive of the alternative oxygenates studied, increasing average costs in the intermediate term by 6.7 cents per gallon compared to MTBE. Under this case, California gasoline demand is met by producing about 748,000 barrels per day of blending materials at California refineries, importing an additional 142,000 barrels per day of these gasoline components, and importing 75,000 barrels per day of ethanol. Equipment modifications to terminals will require approximately 18 to 24 months to complete before the distribution infrastructure is fully capable of dispensing gasoline containing ethanol.

The majority of the ethanol imported to California in the intermediate term is assumed to originate from the midwest region of the United States. although nearly 3,000 barrels per day of California ethanol production is being assessed or is in a planning stage, no construction has begun at this time. It is possible that additional ethanol capacity could eventually be built in California, especially since the facilities should benefit from a 10 cent per gallon (or greater) transportation advantage compared to producers in the Midwest. For purposes of the intermediate term, potential additional ethanol supplies from a California source were not included because the three-year time period was assumed to be too short to allow for the planning, design, financing, permitting and construction of brand new ethanol facilities.

Even though a gallon of ethanol costs more than a gallon of MTBE, refiners would partially offset this price increase by using less in each gallon of gasoline. Since ethanol contains more oxygen than MTBE, less volume is required to reach the desired oxygen content, reducing costs by over $1.1 million per day. Besides reducing their oxygenate costs, refiners also decrease the amount of crude oil purchased for their refineries, saving nearly $2.2 million per

TABLE 2A Results from Alternative Oxygenates Study Demand and Supply of CARB Reformulated Gasoline Using Predictive Model - Average Mode (Thousand Barrels Per Day)					
		Supply			
Oxygenate Cases	Demand for CARB RFG	Blending Materials Produced at California Refineries	Imported Blending Materials	Imported Oxygenates	Total
Intermediate Term					
Base Case	965	846	11	108	965
Ethanol	965	738	152	75	965
ETBE	965	825	11	129	965
TBA	965	843	33	89	965
Mixed	965	853	11	101	965
HR 630	965	847	24	94	965
No Oxygenates	965	599	366	0	965
Long Term					
Base Case	1,022	896	11	115	1,022
Ethanol	1,022	819	124	79	1,022
ETBE	1,022	874	11	137	1,022
TBA	1,022	888	30	104	1,022
Mixed	1,022	885	11	126	1,022
HR 630	1,022	901	21	100	1,022
No Oxygenates	1,022	841	181	0	1,022

*Blending materials consist of CARBOB, alkylates and isomerates.

TABLE 2B Results from Alternative Oxygenates Study Demand and Supply of CARB Reformulated Gasoline Using Predictive Model - Flat Limit Mode (Thousand Barrels Per Day)					
		Supply			
Oxygenate Cases	Demand for CARB RFG	Blending Materials Produced at California Refineries	Imported Blending Materials	Imported Oxygenates	Total
Intermediate Term					
Base Case	965	846	11	108	965
Ethanol	965	779	111	75	965
ETBE	965	825	11	129	965
TBA	965	870	11	84	965
Mixed	965	864	11	90	965
HR 630	965	859	31	75	965
No Oxygenates	965	704	261	0	965
Long Term					
Base Case	1,022	896	11	115	1,022
Ethanol	1,022	845	98	79	1,022
ETBE	1,022	874	11	137	1,022
TBA	1,022	907	16	99	1,022
Mixed	1,022	885	11	126	1,022
HR 630	1,022	917	14	91	1,022

No Oxygenates	1,022	880	142	0	1,022
*Blending materials consist of CARBOB, alkylates and isomerates.					

TABLE 3 Average Cost Change Cents Per Gallon		
	Intermediate Term	**Long Term**
Ethanol	6.1 to 6.7	1.9 to 2.5
ETBE	2.4 to 2.5	0
TBA	0.5 to 1.4	0.3 to 1.0
Mixed Oxygenates	-0.2 to 0.2	-0.3 to -0.4
HR 630	-0.2 to -0.8	-0.3 to -1.5
No Oxygenates	4.3 to 8.8	0.9 to 3.7
One Pound Waiver	4.0 to 5.4	-0.8 to 1.0

day. But all of these savings are surpassed by costs amounting to nearly $5.8 million per day for the following reasons:

- Since ethanol has a higher oxygen content than MTBE, the final volume required to be blended is a little more than half that of MTBE (7.8% versus 11.5%). This difference must be made up with expensive import components, mostly alkylates. Further, ethanol blending into gasoline results in a higher volatility effect which violates California gasoline specifications. To offset this effect, other gasoline components must be removed and replaced with more desirable imports such as alkylates.

- Fewer barrels of crude oil processed by refineries translate into lower output of refined products, namely diesel. This shortfall of 40,000 barrels per day must be imported at a cost of more than $1.0 million per day.

- Costs for modification to the refineries to handle additional movement of gasoline blending components equate to 0.8 cents per gallon.

- Because of ethanol's affinity for water, it cannot be shipped by pipeline like MTBE and other oxygenates. Ethanol must be transported by truck or rail to the terminal for blending into gasoline. This requires special blending equipment and segregated storage tanks to be modified or built. These modifications would amount to $60 million, increase the average cost by 0.1 cents per gallon, and require approximately 18 to 24 months to complete.

- The modest fuel economy penalty that results from using the slightly lower energy content of gasoline containing ethanol adds about 1.0 cents per gallon to the average cost of gasoline.

The lower end of the average cost increase for ethanol is 6.1 cents per gallon. This results from using a flat limit variation of the Predictive Model. The lower cost of the flat limit modeling run demonstrates one outcome of the additional flexibility that is afforded refiners who are able to utilize this version of the predictive model. The decrease from 6.7 to 6.1 cents per gallon is primarily accomplished by cutting back on imports of more expensive gasoline blending components and reducing exports of less valuable refinery components that can no longer be used to make gasoline, diesel or jet fuel in California.

One Pound Volatility Waiver. Current regulations allow refiners to produce gasoline containing 10 percent ethanol with a volatility of 7.8 pounds, but CARB would first have to make a determination that this gasoline blend would not result in any reduction of air quality benefits. At this time, preliminary results of 10 percent ethanol blends in vehicles tested by CARB show that the volatility of 7.8 pounds would cause major increases in hydrocarbon emissions, the ozone-forming potential of those emissions, and benzene emissions--all mostly due to excess evaporative emissions. Higher exhaust emissions of nitrogen oxides would also be expected.

If these findings are adopted later this year by CARB, the regulatory option of a one pound waiver for 10 percent ethanol blends would be precluded. Since the final adoption has not occurred, the Energy Commission examined a case of a one pound waiver to see what the impact could be on the production costs of reformulated gasoline for California refineries.

With an allowance for refiners to make gasoline with a higher volatility, the refinery modeling results indicate that the feasibility of this case hinges on which variation of the Predictive Model is used by refiners. In average mode, refiners would be forced to decrease the amounts of sulfur, aromatics and olefins to levels much lower than today's gasoline in order to get a recipe of gasoline to pass the Predictive Model. This practice would necessitate importing over 50 percent of our gasoline needs, significantly increasing the price of gasoline for consumers.

Use of the average mode of the Predictive Model leads to an infeasible case in both the intermediate and long term timeframes.

If refiners used the flat limit mode of the Predictive Model, complying gasoline can be produced at an average cost increase of 5.4 cents per gallon in the intermediate term and 1.0 cents per gallon in the long term. These additional costs would amount to nearly $800 million in the intermediate term and $157 million in the long term. As much as 103,000 barrels per day of ethanol and 50,000 barrels per day of additional gasoline imports would be required to meet demand.

Another interpretation of the regulatory language associated with the one pound volatility waiver is a formulation of reformulated gasoline that is similar to the flat limit recipe, except for a higher volatility of 7.8 pounds and an oxygen content of 3.5 weight percent. Refinery modeling results indicate that this blend of gasoline can be produced at an average cost increase of 4.0 cents per gallon in the intermediate term. In the long term, this blend of gasoline can be produced at an average cost decrease of 0.8 cents per gallon.

ETBE

ETBE is a less expensive option than ethanol, but its use will still increase the average cost of gasoline by 2.4 cents per gallon compared to MTBE. Under this case, California gasoline demand is met by producing about 825,000 barrels per day of blending material at California refineries and importing 129,000 barrels per day of ETBE.

ETBE has more desirable blending characteristics that allow refiners to eliminate the need for additional imports of gasoline components and thereby reduce any investments at the refinery and distribution infrastructure. In addition, the increased use of ETBE allows refiners to slightly reduce their use of crude oil, which will save nearly $940,000 per day.

These savings are offset by the increased costs of $1.4 million per day for the total volume of ETBE required to meet the desired oxygen content. In addition, the modest fuel economy penalty that results from use of the slightly lower energy content of gasoline containing ETBE adds 0.5 cents per gallon to the average cost increase.

Operating the refinery model in the flat limit mode appears to have little impact on the average cost, actually increasing it from 2.4 to 2.5 cents per gallon.

TBA

TBA is slightly less expensive, increasing average costs by only 1.4 cents per gallon more than gasoline containing MTBE. Under this case, California gasoline demand is met by producing about 843,000 barrels per day of blending materials at California refineries, importing an additional 22,000 barrels per day of gasoline components, and importing 89,000 barrels per day of TBA.

Similar to ethanol, the use of TBA allows refiners to reduce their total oxygenate cost and slightly reduce the amount of crude oil purchased for processing at the refinery. These savings of more than $930,000 per day are nearly offset by the cost of $723,000 per day to import additional volumes of gasoline components. Refiners must also export, at a net loss, approximately 3,000 barrels per day of refinery components that are no longer suitable for use in gasoline, diesel or jet fuel. In addition, refiners would have to make close to $12 million in modifications to accommodate the use of TBA in gasoline.

Operating the refinery model in the flat limit mode also reduces the average cost for using TBA, decreasing from 1.4 to 0.5 cents per gallon. The additional flexibility allows refiners to eliminate the need to import additional gasoline blending components and eliminate the need to export undesirable blending components. Refinery investment becomes unnecessary in this case, saving $12 million. Finally, there is a slight fuel economy benefit that reduces the cost by about 0.2 cents per gallon.

Mixed Oxygenates

An economically optimal combination of more than one type of oxygenate turns out to be the least costly of all the alternatives studied, increasing the average cost of gasoline by only 0.2 cents per gallon when compared to using MTBE in gasoline. In this case, California gasoline demand is met by producing about 853,000 barrels per day of blending materials at California refineries and importing a combined 101,000 barrels per day of ETBE and TBA. No volume of TAME was selected for this case because the cost of this oxygenate was greater than either TBA or ETBE.

These results are not surprising considering the fact that the supply of TAME is limited to small volumes located at individual refineries scattered throughout the country. The diffuse nature of the TAME supply tends to increase the costs for gathering and transporting this alternative oxygenate to California, so much so that ETBE and TBA become less expensive in comparison to TAME.

The refinery modeling results indicate that the combination of 66,000 barrels per day of ETBE and 35,000 barrels per day of TBA used in gasoline would allow refiners to reduce their crude oil use by some 9,000 barrels per day, saving over $170,000 per day. Since the type of gasoline produced in this case has a slightly lower energy content than gasoline containing MTBE, the average cost increases by 0.1 cents per gallon. Similar to the ETBE case, refiners do not have to make any modifications to their refineries or distribution infrastructures and can eliminate the need to import additional volumes of more expensive gasoline components. The additional costs associated with purchasing these two oxygenates total nearly $26,000 per day.

Operating the refinery model in the flat limit mode afford additional flexibility, allowing the average cost impact to change from an increase of 0.2 cents per gallon to a decrease of 0.2 cents per gallon.

In this case, California gasoline demand is met by producing about 864,000 barrels per day of blending materials at California refineries and importing a combined 90,000 barrels per day of ETBE and TBA. The savings of over $510,000 per day from reduced use of oxygenates are more than enough to overcome the $340,000 per day cost of higher crude oil purchases.

Impacts of H.R. 630

Staff examined the impacts of allowing the whole state to make gasoline with less than the minimum oxygen content currently required and found that the average cost for producing gasoline containing smaller amounts of MTBE decreased by 0.2 cents per gallon. If refiners were to use the flat limit variation of the Predictive Model, the average cost decrease would be 0.8 cents per gallon. The impact of H.R. 630 on the average costs of other alternative oxygenates could be similar for the two timeframes.

No Oxygenates Case

If all oxygenates were discontinued for use in gasoline, the cost impact would be even greater than any of the alternative oxygenates studied under the intermediate term. Findings indicate that the average cost increase of gasoline for California consumers would range from 4.3 to 8.8 cents per gallon. The lower value is a result of the refiners using the flat limit variation of the Predictive Model. This case would require the passage of H.R. 630.

Under this case, California gasoline demand is met by producing about 599,000 barrels per day of blending material at California refineries and importing 355,000 barrels per day of additional gasoline components. Eliminating the need to import oxygenates and reducing the use of crude oil by about 120,000 barrels per day saves the refiners more than $6.3 million per day. Even with an additional fuel economy benefit of 0.5 cents per gallon, these savings are still not sufficient to overcome the costs of approximately $12.3 million per day of imports of gasoline components and 54,000 barrels per day of additional diesel and jet fuel. In addition, over 200,000 barrels per day of refinery components must be exported because they are unsuitable for blending into gasoline, diesel or jet fuel in California.

Under the flat limit mode of the Predictive Model the average cost increase declines from 8.8 to 4.3 cents per gallon. Under this case, average costs are significantly lower primarily because imports of additional gasoline components have been reduced by 105,000 barrels per day at a savings of over $3.2 million per day. The potential burden on the marine terminal infrastructure is also lessened because exports of refinery components have been reduced from 203,000 to 126,000 barrels per day.

It should also be noted that these large volumes of imports and exports could place a substantial strain on the marine terminal infrastructure, most notably a potential limitation of U.S. tankers required to move much of these petroleum products from the Gulf Coast to California.

Long Term Analysis (Six Years)

The long term analysis examines the impact of phasing out MTBE over a six year period. All assumptions used in the intermediate term are in effect with two exceptions:

- In addition to minor debottlenecking, refiners would have sufficient time to make major process unit modifications such as equipment replacement or capacity expansions.
- Additional new oxygenate capacity could be brought on line with the construction of new facilities.

In the long term, demand for gasoline in California is expected to be 1,022,000 barrels per day. As shown previously in Tables 2A and 2B, the amount of materials produced at the refinery or imported will vary depending upon the oxygenate. Table 3 displays the resulting changes in average costs. Below is a discussion of each oxygenate.

Ethanol

Ethanol is the most expensive of the alternative oxygenates studied, increasing average costs in the long term by 2.5 cents per gallon compared to MTBE. Under this case, California gasoline demand is met by producing about 819,000 barrels per day of blending materials at California refineries, importing an additional 113,000 barrels per day of these blending materials, and importing 79,000 barrels per day of ethanol.

The majority of the ethanol imported to California in the long term is assumed to originate from the midwest region of the United States. although nearly 3,000 barrels per day of California ethanol production is being assessed or is in a planning stage, no construction has begun at this time. It is possible that additional ethanol capacity could eventually be built in California, especially since the facilities should benefit from a 10 cent per gallon (or greater) transportation advantage compared to producers in the Midwest. For purposes of the six-year timeframe, potential additional ethanol supplies from a California source were not included because the production costs of new facilities using corn were not competitive with either existing or new ethanol plants in the Midwest.

In addition, production costs of potential new ethanol plants in California using alternative biomass sources (such as rice straw by the proposed Gridley Project) have not yet been quantified on a commercial scale basis. Staff assumed that these facilities would be competitive if they are able to produce and deliver ethanol to California refiners at a price below that of Midwest suppliers.

Since ethanol contains more oxygen per gallon than MTBE, less volume is required to reach the desired oxygen content. Consequently, refiners are able to save about $1.7 million per day in oxygenate costs. Besides these savings, refiners also decrease the amount of crude oil purchased for the refineries, saving about $1.2 million per day. However, these savings are surpassed by costs amounting to nearly $3.8 million per day for the following reasons:

- Since ethanol has a higher oxygen content than MTBE, the final volume required to be blended is a little more than half that of MTBE (7.8% versus 11.5%). This difference must be made up with expensive import components, mostly alkylates. Further, ethanol blending into gasoline results in a higher volatility effect which violates California gasoline specifications. To offset this effect, other gasoline components must be removed and replaced with more desireable imports such as alkylates.

- The modest fuel economy penalty that results from using the slightly lower energy content of gasoline containing ethanol adds about 0.7 cents per gallon to the average cost of gasoline.

- Unlike the intermediate term, this scenario allows for some refinery investment for major process modifications. In the case of ethanol, these investments total $59 million.

- Refiners would need to make certain modifications to storage tanks and gasoline blending equipment located at various points in their distribution infrastructure so that gasoline containing ethanol could be dispensed throughout the state. These modifications would amount to $60 million, increase the average cost by 0.1 cents per gallon, and require approximately 18 to 24 months to complete.

The lower end of the average cost increase range for ethanol is 1.9 cents per gallon. This lower cost is the result of operating the refinery model using a flat limit variation of the Predictive Model. The lower cost of these flat limit modeling runs demonstrate the additional flexibility that is afforded refiners who are able to utilize this version of the Predictive Model. The decrease from 2.5 to 1.9 cents per gallon is a result of refiners cutting back on imports of more expensive gasoline blending components by using locally produced components and reducing investment in refinery modifications from $59 to $38 million.

One Pound Volatility Waiver. With an allowance for refiners to make gasoline with a higher volatility, the refinery modeling results indicate that the feasibility of this case hinges on which variation of the Predictive Model is used. In average mode, refiners would be forced to decrease the amounts of sulfur, aromatics and olefins to levels much lower than today's gasoline in order to get a recipe of gasoline to pass the Predictive Model. This practice would necessitate importing over 50 percent of our gasoline needs, significantly increasing the price of gasoline for consumers. Use of the average mode of the Predictive Model leads to an infeasible case in both the intermediate and long term timeframes.

If refiners used the flat limit mode of the Predictive Model, complying gasoline can be produced at an average cost increase of 5.4 cents per gallon in the intermediate term and 1.0 cents per gallon in the long term. These additional costs would amount to nearly $800 million in the intermediate term and $157 million in the long term. As much as 103,000 barrels per day of ethanol and 50,000 barrels per day of additional gasoline imports would be required to meet demand.

ETBE

ETBE is a less expensive option than ethanol. Compared to MTBE, the cost of using ETBE is roughly the same. Under this case, California gasoline demand is met by producing about 874,000 barrels per day of blending materials at California refineries and importing 137,000 barrels per day of ETBE.

ETBE has more desirable blending characteristics that allow refiners to eliminate the need for additional imports of gasoline components and avoid any investments at the refinery or throughout the distribution infrastructure. In addition, the increased use of ETBE allows refiners to slightly reduce their use of crude oil, which will save over $930,000 per day.

These savings are offset by the increased costs of nearly $1 million per day for the total volume of ETBE required to meet the desired oxygen content. In addition, the modest fuel economy penalty that results from use of the slightly lower energy content of gasoline containing ETBE adds 0.5 cents per gallon to the average cost increase. Operating the refinery model in the flat limit mode appears to have little impact on the average cost, which shows no increase or decrease in both cases.

TBA

In the long term, TBA is less expensive than ethanol, increasing average costs by only 1.0 cents per gallon more than gasoline containing MTBE. Under this case, California gasoline demand is met by producing about 888,000 barrels per day of blending materials at California refineries, importing an additional 18,000 barrels per day of these materials, and importing 104,000 barrels per day of TBA.

Similar to ethanol, the use of TBA allows refiners to reduce their total oxygenate cost and slightly reduce the amount of crude oil purchased for processing at the refineries. These savings of over $510,000 per day are offset by the need to spend nearly $592,000 per day to import additional volumes of gasoline components. In addition, refiners would have to make close to $38 million worth of modifications to their facilities to accommodate the use of TBA in gasoline.

Operating the refinery model in the flat limit mode also reduces the average cost for using TBA, decreasing from 1.0 to 0.3 cents per gallon. In other words, the flat limit mode would allow refiners to make gasoline with TBA for nearly the same cost compared to producing gasoline with MTBE. This additional flexibility allows refiners to reduce their need to import additional gasoline blending components. Refinery investment also declines from $38 to less than $2 million, saving $36 million. A slight increase in the amount of crude oil purchased by refiners, an additional cost of $623,000 per day, is nearly offset by the $500,000 per day saved in the cost of oxygenates. Finally, there is a slight fuel economy benefit that reduces the average cost by about 0.2 cents per gallon.

Mixed Oxygenates

An economically optimal combination of more than one type of oxygenate turns out to be the least costly of all the alternatives studied, actually decreasing the average cost of gasoline by 0.3 cents per gallon when compared to using MTBE. Under this case, California gasoline demand is met by producing about 885,000 barrels per day of blending materials at California refineries and importing a combined 126,000 barrels per day of ETBE and TBA. No volume of TAME was selected under this case because the cost of this oxygenate was greater than either TBA or ETBE, for the same reasons cited in the intermediate term discussion. Results indicate that the combination of 101,000 barrels per day of ETBE and 25,000 barrels per day of TBA used in gasoline would allow refiners to reduce their crude oil use by some 30,000 barrels per day at a savings of over $570,000 per day. Similar to the ETBE case, refiners do not have to make any modifications to their refineries or improvements to their distribution infrastructures and can eliminate the need to import additional volumes of more expensive gasoline components.

The additional costs associated with purchasing oxygenates total a little more than $500,000 per day. Since the type of gasoline produced in this case has a slightly lower energy content than gasoline containing MTBE, the average cost increases by 0.3 cents per gallon.

Operating the refinery model in the flat limit mode changes the results from a decrease of 0.3 to 0.4 cents per gallon. The only significant difference between the two cases is the slightly lower fuel economy penalty of 0.2 cents per gallon.

Impacts of H.R. 630

In the long term, the benefits of allowing relaxation of the federal minimum oxygen requirement through passage of H.R. 630 could benefit California consumers by reducing the average cost of gasoline between 0.3 and 1.5 cents per gallon. Under this case, California gasoline demand is met by producing about 901,000 barrels per day of blending materials at California refineries, importing an additional 10,000 barrels per day of these materials, and importing 100,000 barrels per day of MTBE. The benefit of H.R. 630 is the additional flexibility which allows refiners to reduce their use of MTBE by 13 percent.

Under the flat limit variation of the Predictive Model, the average cost declines from 0.3 to 1.5 cents per gallon savings for consumers. The bigger savings are primarily a result of decreasing the use of oxygenates by 9,000 barrels per day and eliminating 7,000 barrels per day of additional gasoline component imports. The additional benefit of H.R. 630 under the flat limit mode is that it allows refiners to reduce their use of MTBE by nearly 21 percent.

No Oxygenates Case

In the long term, a complete ban on all oxygenates would result in the greatest average cost increase for gasoline for this time period compared to all of the other alternatives studied. These cost increases range from 0.9 to 3.7 cents per gallon. The lower value is a result of refiners operating under the flat limit variation of the Predictive Model. This case would require the passage of H.R. 630.

Under this case, California gasoline demand is met by producing about 841,000 barrels per day of blending materials at California refineries and importing 170,000 barrels per day of additional gasoline components. Eliminating the need to import oxygenates saves the refiners a little more than $4.0 million per day. Even though the cost of imports is roughly the same at $5.3 million per day and a fuel economy benefit of 0.9 cents per gallon is achieved, refiners would need to make significant investments to modify their facilities, totaling over $1.1 billion. This is the primary reason for the average cost increase.

Under the flat limit mode of the Predictive Model the average cost increase declines from 3.7 to 0.9 cents per gallon. Under this case, average costs are significantly lower primarily because refinery investment has been reduced by over $710 million and imports of additional gasoline components have been reduced by 39,000 barrels per day at a savings of over $1.1 million per day.

Potential Impacts Of U.S. MTBE Phase-Out

The Energy Commission recognizes that if MTBE were to be phased out of use in California, the rest of the United States could follow suit. Staff intends to examine the potential impacts of this case in greater detail and present these findings in the ***Fuels Report*** to be published by the Energy Commission following completion of the this study. As part of the preparation of the main body of this additional work, we have examined the implications of a phase out of MTBE in the rest of the U.S. on the supply and price of various oxygenates. As an example, we have also included the refinery modeling results of this case, with ethanol as the alternative. These findings indicate that the higher level of demand that would result increases the cost of ethanol to California, thereby increasing the total oxygenate costs for refiners. Directionally speaking, the average cost of California gasoline increases from 6.7 to 11.7 cents per gallon in the intermediate term and from 2.5 to 3.7 cents per gallon in the long term. Impacts on the average costs of the other alternative oxygenate cases are expected to be similar to this example.

List Of Abbreviations

CARB	California Air Resources Board
CARBOB	California Reformulated Gasoline Blendstock for Oxygen Blending
EPA	Environmental Protection Agency
ETBE	Ethyl Tertiary Butyl Ether
MTBE	Methyl Tertiary Butyl Ether
RFG	Reformulated Gasoline
Rvp	Reid Vapor Pressure
TAME	Tertiary Amyl Methyl Ether
TBA	Tertiary Butyl Alcohol