Supply Impacts of an MTBE Ban

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Contacts

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On June 17, 2002, Senator Jeff Bingaman, Chairman of the Senate Committee on Energy and Natural Resources, requested (Appendix A) that the Energy Information Administration (EIA) provide analysis of eight factors related to the Senate-passed fuels provisions of H.R. 4, the Energy Policy Act of 2002. In response, EIA has prepared a series of analyses discussing the market impacts of each of these factors. This analysis addresses factor number 1 of the Senator's request.

Because of the rapid delivery time requested by Sen. Bingaman, each requested factor related to the Senate-passed bill was analyzed separately, that is, without analyzing the interactions among the various provisions. In addition, assumptions about State actions, such as their implementation and timing of MTBE bans, influence the results. Discussions about some of these interactions have been included in order to explain the interconnected nature of such issues.

EIA's projections are not statements of what will happen but what might happen, given known technologies, technological and demographic trends, and current laws and regulations. EIA's *Annual Energy Outlook 2002 (AEO2002*) is used in these analyses to provide a policy-neutral Reference Case that can be used to analyze energy policy initiatives. EIA does not propose, advocate or speculate on future legislative or regulatory changes. Laws and regulations are assumed to remain as currently enacted or in force in the Reference Case; however, the impacts of emerging regulatory changes, when clearly defined, are reflected.

The analyses involve simplified representations of reality because of the complexity of both the issues examined and the environment in which they would occur. Projections are highly dependent on the data, methodologies, and assumptions used to develop them. Because many of the events that shape energy markets (including severe weather, technological breakthroughs, and geopolitical disruptions) are random and cannot be anticipated, energy market projections are subject to significant uncertainty. Further, future developments in technologies, demographics, and resources cannot be foreseen with any degree of certainty. These uncertainties are addressed through analysis of alternative cases in the *AEO2002*.

Introduction

This paper analyzes the supply impacts of removing MTBE from gasoline. While the question asked for an analysis of an effective ban in 2004, this analysis uses 2007, the first year of the proposed Federal Ban. A supply-demand balance calculation was developed that compares a no-ban case to a full Federal ban. MTBE bans are scheduled to begin in 2004, but there was insufficient time to address each transition from 2004 to 2007 in this analysis. EIA's response to Factor 2 addresses timing of the various State bans in relationship to the proposed Federal ban at an aggregate level for the United States. It does not analyze the impact on individual refineries nor the impact at a localized level.

MTBE currently provides more than 260 thousand barrels per day of volume to gasoline. It adds over 10 percent to reformulated gasoline (RFG)[1] volumes, and represents about 3 percent of total gasoline demand. Most MTBE is used in RFG, but this has not always been the case. Prior to the reformulated gasoline program, MTBE was mainly used in gasoline as a high-octane blending component to replace the octane lost when lead was removed. In 1992, because MTBE contains oxygen, MTBE use increased as oxygenated gasoline was required under the Clean Air Act Amendments. Its use increased even more as the reformulated gasoline program began in 1995.[2] since MTBE met both oxygen requirements in RFG as well as other emission and engine performance properties.

Because no other oxygenate or hydrocarbon can match MTBE's low air pollution properties and gasoline performance, removing MTBE results in more than a 3-percent loss of gasoline supply. Furthermore, this supply loss is occurring at a time when refinery capacity is being strained by other regulatory changes such as the move to low sulfur gasoline.

Most MTBE today is used on the East and West Coasts where 42 and 37 percent, respectively, of the nation's RFG is consumed. Although some small volumes of MTBE are still used in conventional gasoline in the Midwest, this region primarily uses ethanol rather than MTBE to meet oxygen requirements in RFG. Thus, the loss of MTBE will affect the East and West Coasts more than other regions of the country.

This paper begins with an overview of gasoline properties that affect emissions and engine performance and discusses how MTBE, ethanol, and other gasoline components affect those properties, which set the stage for why ethanol is one of the likely substitutes for MTBE. The paper continues with the adjustments that need to be made to gasoline when MTBE is removed and ethanol added, showing how gasoline production capability is reduced for an individual refinery. A regional supply-demand balance is developed and is followed by an analysis of the aggregate effects of an MTBE ban for two scenarios. Factors that could reduce supply, but that could not be quantified in this analysis, are noted.

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[1] Reformulated gasoline (RFG) is gasoline that, on average, significantly reduces Volatile Organic Compounds (VOC) and air toxics emissions relative to conventional gasolines. It is more difficult to produce than conventional gasoline and originally was required only in the nine cities with the worst smog (Los Angeles, San Diego, Chicago, Houston, Milwaukee, Baltimore, Philadelphia, Hartford, and New York City). Other areas that also have a history of smog problems joined the RFG program. Today, RFG represents about 1/3 of gasoline consumption.

[2] Approximately 95 percent of MTBE is used in RFG. See "MTBE, Oxygenates, and Motor Gasoline," Energy Information Administration, February 2000, http://www.eia.doe.gov/emeu/steo/pub/special/mtbe.html#Which%20areas%20get%20MTBE .

Factors Affecting Emissions and Engine Performance

The RFG emissions that are regulated under the Clean Air Act Amendments are volatile organic compounds (VOCs), nitrogen oxides (NO_x), and toxics. These emissions are estimated for regulatory purposes using the complex model, which was developed by EPA to relate gasoline properties and composition to the regulated emissions. Similarly, the California Air Resources Board (CARB) developed the CARB predictive model, with more stringent emission requirements than the Federal complex model. These tools allow refiners to adjust their gasoline blends according to their own needs to meet emission requirements. The primary gasoline physical properties in these models that affect emissions are vapor pressure and distillation profile (measured by E200 and E300 in the Federal model or T50 and T90 in the California predictive model), and the main chemical components that adversely affect emissions are aromatics, olefins, benzene, and sulfur content.

Distillation Profile
Gasoline is made up of many different chemical components, which boil at different temperatures. This characteristic can be measured in terms of the percent of material that has boiled or distilled at a given temperature. For example, T50 is the temperature at which 50 percent of gasoline would evaporate under certain conditions. T10, T50, and T90 are measures frequently used to describe a distillation profile for a given blend of gasoline. Similarly, the distillation profile can be described in terms of the percent of material that has evaporated at a given temperature. For example, E200 and E300 are the volume percents of material that would boil away at 200°F and 300°F, respectively.

The oxygen content in gasoline is also a factor in making reformulated gasoline. Currently, a minimum of 2 percent by weight oxygen is required. MTBE and ethanol are the two primary oxygenates used in reformulated gasoline. MTBE has half as much oxygen content by weight as does ethanol, so twice as much volume of MTBE is needed to meet the 2-percent-by-weight requirement. Generally, this translates to about 11.2 percent by volume of MTBE and 5.8 percent by volume ethanol.[3]

When refiners change gasoline physical and chemical properties to meet emission requirements, they must also maintain engine performance. Engine performance, like emissions, is influenced by vapor pressure and distillation profile. For example, if the vapor pressure is too low during the winter, consumers may have trouble starting their engines. Octane is another important property for engine performance that is affected by the shift from MTBE to ethanol, but it does not affect emissions.

Table 1 shows the physical and chemical properties of MTBE and some other gasoline blending components. This table gives the physical and chemical properties for blend

[3] The MTBE and ethanol volume percents will vary slightly depending on the specific gravity of the base gasoline blend to which the oxygenate is being added.

components that affect emissions as defined by the CARB predictive model and the Federal complex model. MTBE is the most attractive component from an emissions perspective because it has no sulfur, aromatics, or olefins, which contribute to air emissions. In addition, MTBE has some important indirect benefits. When MTBE is added, it dilutes those chemical properties in the blend that increase air emissions, reducing their average concentration. Furthermore, MTBE's distillation profile and vapor pressure require little if any adjustment to the base gasoline to which it is added. MTBE's high octane allows refiners to reduce the severity at which they run their reformers, which in turn reduces the aromatic content of the reformulated gasoline. The remainder of this report will describe in more detail what refiners must do to replace MTBE, should its use be banned.

Table 1. Emission Related Chemical and Physical Properties of Gasoline Blend Components

Properties	MTBE	Ethanol	LSR - C_5-200	Isomerate	Alkylate	Reformate	FCC Gasoline
Octane: (R+M)/2	110	113	63	83	92-94	86-94	86
RVP: psi	8	see note	10	12	4-6	4	6-7
E200: vol%	100	100	100	100	30	0	47
E300: vol%	100	100	100	100	94	70-80	77
Benzene: vol%	0	0	.01-3.0	0	0.1	0.2-3.0	0.5-1.0
Aromatics: vol%	0	0	.01-3.0	0	0.4	50-65	20-30
Olefins: vol%	0	0	0	0	0.5	0	25-40
Sulfur: ppm	0	0	0-200	0	0	0-25	100-1,500
Oxygen: wt%	18.2	34.7	0	0	0	0	0

Note: Ethanol exhibits a high vapor pressure when blended with the hydrocarbons of a gasoline blend. The RVP impact of the ethanol is quite non-linear. The addition of 5 percent ethanol to a base 9 RVP gasoline will raise the RVP by slightly over 1 psi, while the addition of 10 percent ethanol will increase the mixture a little less than 1psi.

Definitions of abbreviations and technical terms:
MTBE = methyl tertiary butyl ether;
LSR = light straight run gasoline
FCC = fluid catalytic cracking;
RVP = Reid vapor pressure;
ppm = parts per million;
psi = pounds per square inch;
vol% = volume percent; wt% = weight percent.

Sources: American Petroleum Institute. *Alcohols and Ethers: A Technical Assessment of Their Application as Fuels and Fuel Components* (Washington, DC: API Publication 4261); and Piel, W.J. and R.X. Thomas. "Oxygenates for reformulated gasoline," *Hydrocarbon Processing* (July 1990), p. 68.

While MTBE has no equivalent substitute, ethanol should play an important role in helping to fill any gap left by the banning of MTBE. First, RFG regulations require the use of 2 percent oxygen by weight. Apart from other ethers, ethanol is the only practical alternative to meet that oxygen requirement. In addition to its oxygen content, ethanol has other attractive features that make it a desirable material to use in the production of RFG, such as high octane. However, ethanol has different physical and chemical properties than MTBE, and, thus, the two oxygenates have different effects on emissions and engine performance. These differences are at the root of much of the volume issue surrounding replacement of MTBE with ethanol in RFG.

MTBE and Ethanol Emission Comparison

Both MTBE and ethanol are relatively clean components compared to many other gasoline components; however, they affect emissions differently. Within the Federal complex model, the different impacts of MTBE and ethanol on VOCs and toxics are the main factors that ultimately lead to the reduction in RFG production capability. The Federal complex model's NO_x emissions are relatively insensitive to the switch from MTBE to ethanol, but this is not the case with the California predictive model, which is discussed in Appendix B.

Federal reformulated gasoline requirements, for the most part, are stated in terms of emission reductions required from an industry base gasoline (Table 2). The industry base gasoline as well as emission reductions are defined in EPA's Final Rule on Reformulated Gasoline.[4] Note that VOC and NO_x emission reductions are required during the summer. Table 3 shows the properties of that base gasoline, and in the column at the bottom far right, it shows what reductions are necessary from that baseline gasoline to meet reformulated gasoline emission requirements.

RVP Differences Between MTBE and Ethanol

RVP is the primary physical characteristic that affects VOC emissions. MTBE has a slightly higher blending RVP than the other gasoline components to which it is added. When 11.2 percent volume of MTBE is blended with these other components to create a finished RFG of about 7.0 RVP, the final mixture's RVP is 0.16 psi higher than the RVP of the non-MTBE components comprising 88.8 percent of the final mixture. In contrast, when 5.8 percent ethanol is added to other components (representing 94.3 percent of the final mixture), the ethanol raises the RVP of the final mixture 1.30 psi or more over the RVP of the non-ethanol components. Thus, the base blend to which ethanol is to be added must have an RVP 1.14 psi lower than a base blend to which MTBE is to be added.

In the column next to the base gasoline is an RFG blend that uses MTBE. Using the complex model to estimate emissions, the 11.2-percent MTBE case shows that VOCs are almost 26 percent lower than the industry baseline fuel, toxics are over 33 percent lower, and NO_x emissions are reduced by about 8 percent. The Federal requirements are shown in the far right column. Table 3 shows that the MTBE blend far exceeds Federal requirements in everything except VOCs, where it just meets that requirement.

[4] 40CFR, Part 80, Subpart D.

Using the complex model, the next column of the table illustrates the emission changes that would occur when MTBE is removed and ethanol is put into the gasoline. No other changes are made to the gasoline.

Table 2. Summary of Complex Model
RFG Per Gallon Performance Standards for Phase II

Pollutant	Region (1)	Season	Standard
VOC(2)	Region 2 (Northern)	VOC control(3)	≥ 27.5% reduction
	Region 1 (Southern)	VOC control	≥ 25.9% reduction
Toxics	All	All	≥ 20.0% reduction
NOx	All	VOC control	≥ 5.5% reduction
Benzene (percent by volume)			≤ 1.0

(1)As defined in 40 CFR 80.71, VOC Control Region 1 covers: Alabama, Arizona, Arkansas, California, Colorado, District of Columbia, Florida, Georgia, Kansas, Louisiana, Maryland, Mississippi, Missouri, Nevada, New Mexico, North Carolina, Oklahoma, Oregon, South Carolina, Tennessee, Texas, Utah, and Virginia. VOC Control Region 2 covers: Connecticut, Delaware, Idaho, Illinois, Indiana, Iowa, Kentucky, Maine, Massachusetts, Michigan, Minnesota, Montana, Nebraska, New Hampshire, New Jersey, New York, North Dakota, Ohio, Pennsylvania, Rhode Island, South Dakota, Vermont, Washington, West Virginia, Wisconsin, and Wyoming.
(2) 66 FR 37156; July 17, 2001 is the regulation that allows a small adjustment to VOC performance standard in the RFG areas of Chicago and Milwaukee for RFG blends that contain 10 percent by volume of ethanol. The VOC performance standard is a 27.4 percent reduction from the baseline fuel. For complying RFG in Chicago and Milwaukee, the adjusted standard is 25.4 percent.
(3) VOC control season refers to “High ozone season” as defined in 40 CFR 80.27(a)(1) and is the period from June 1 to September 15 for retail outlets and wholesale purchaser-consumers.
Source: 40 CFR 80.41(e)

Many refiners will only use 5.8 percent ethanol in their RFG, rather than higher amounts, both for economical and emission constraint reasons. With 5.8 percent ethanol, all emissions are higher than with 11.2 percent MTBE, but only VOC emissions do not achieve Federal reformulated gasoline requirements. A refiner would have to remove other light, high-RVP components to bring the VOCs within Federal limits. Although the toxics are within reformulated gasoline requirements, they violate the Mobile Source Air Toxics Rule (MSAT)[5] for this refiner. MSAT caps refiners at their average toxic emission level achieved in 1998-2000.[6] The toxics in the 5.8-percent ethanol case at 61.4 mg/mi are higher than in the MTBE case at 57.1 mg/mi, which violates MSAT’s anti-backsliding restriction. The major toxic component causing the difference is a large increase in acetaldehyde. A refiner, when switching from MTBE RFG to ethanol-blended RFG, would have to make further refinery process changes to reduce toxics.

For a refiner that wants to use 10 percent ethanol in RFG, most emissions are higher than when using MTBE, as was the case when using 5.8 percent ethanol. Again, toxics and NO_x fall within the Federal RFG requirements, while VOC emissions exceed Federal

[5] *Control of Emissions of Hazardous Air Pollutants from Mobile Sources*, Final Rule, 40 CFR Part 80, 86.
[6]When a refiner produces more volume than they did in 1998-2000, the incremental volume is allowed to emit toxics at the industry average.

Table 3. Summer Emission Effects of Replacing MTBE with Ethanol in Reformulated Gasoline								
Property	**Baseline Fuel**	**MTBE 11.2 Volume Percent**		**Ethanol 5.8 Volume Percent**		**Ethanol 10 Volume Percent**		**Federal RFG Emission Requirements**
		Target Fuel Properties		**Target Fuel Properties**		**Target Fuel Properties**		
MTBE (wt% oxygen)	0	2.0		0.0		0.0		
ETBE (wt% oxygen)	0	0.0		0.0		0.0		
Ethanol (wt% oxygen)	0	0.0		2.0		3.5		
TAME (wt% oxygen)	0	0.0		0.0		0.0		
Sulfur (ppm)	339	132.0		140.0		133.8		
RVP (psi)	8.7	6.4		7.5		7.4		
E200 (%)	41	45.9		42.6		45.2		
E300 (%)	83	77.3		75.9		77.0		
Aromatics (vol%)	32	25.7		27.3		26.1		
Olefins (vol%)	9.2	9.1		9.6		9.2		
Benzene (vol%)	1.53	0.3		0.4		0.3		
	mg/mi	**mg/mi**	**Percent Change from Baseline**	**mg/mi**	**Percent Change from Baseline**	**mg/mi**	**Percent Change from Baseline**	
Exhaust VOC	907.0	790.9	-12.80	856.2	-5.60	822.7	-9.29	
Nonexhaust VOC	492.1	245.5	-50.11	326.2	-33.71	316.0	-35.78	
Total VOC	**1,399.1**	**1,036.4**	**-25.92**	**1,182.4**	**-15.48**	**1,138.7**	**-18.61**	
Exhaust benzene	53.5	28.6	-46.55	29.7	-44.60	26.9	-49.83	
Nonexhaust benzene	5.5	0.7	-87.26	1.0	-82.43	0.9	-83.58	
Acetaldehyde	4.4	4.2	-6.09	7.6	71.76	10.9	144.71	
Formaldehyde	9.7	11.8	22.08	10.7	10.40	10.8	10.97	
Butadiene	9.4	9.1	-3.27	9.6	2.14	8.8	-6.40	
POM	3.0	2.7	-12.80	2.9	-5.60	2.8	-9.29	
Total exhaust toxics	80.1	56.4	-29.65	60.4	-24.54	60.0	-25.06	
Total toxics	**85.6**	**57.1**	**-33.35**	**61.4**	**-28.26**	**60.9**	**-28.82**	
NO_x	**1340.0**	**1231.3**	**-8.11**	**1243.6**	**-7.20**	**1234.5**	**-7.87**	
VOC Reduction			**-25.92**		**-15.48**		**-18.61**	≥25.9-percent Reduction
Toxics Reduction			**-33.35**		**-28.26**		**-28.82**	≥20.0-percent Reduction
NO_x Reduction			**-8.11**		**-7.20**		**-7.87**	≥5.5-percent Reduction
Benzene Vol%		**0.3**		**0.4**		**0.3**		≤1.0 volume percent

Definition of abbreviations and technical terms:

wt% = weight percent;
ppm = parts per million;
psi = pounds per square inch;
vol% = volume percent;
VOC = volatility organic compounds;
POM = polycyclic organic materials;
mg/mi = milligrams per mile;
MTBE = methyl tertiary butyl ether;
ETBE = ethyl tertiary butyl ether;
TAME = tertiary amyl methyl ether;
RVP = Reid vapor pressure.

Source: Energy Information Administration.

RFG limits. Since toxic emissions are greater than in the MTBE case, the 10-percent ethanol-blend gasoline would not meet this refiner's MSAT requirement. The 10-percent case provides an illustration of another dimension when using ethanol. Comparing the toxics in the 5.8-percent case to the 10-percent case, note that two effects are occurring: acetaldehyde increased when moving from 5.8 to 10 percent ethanol, but other toxics declined. A dilution effect occurs as the 10 percent ethanol dilutes the content of sulfur and aromatics, which are the main determinants of exhaust benzene. So exhaust benzene (and most other toxic components) drop when moving from 5.8 to 10 percent ethanol, but they do not drop enough to match MTBE's toxic performance.

Substituting Ethanol for MTBE in Gasoline

This section outlines the adjustments refiners must make to gasoline when substituting ethanol for MTBE and the changes they must make to recover the resulting lower volumes. Figure 1 highlights the factors that will be covered.

Figure 1. Refinery Impacts of An MTBE Ban

Summer Loss of Gasoline Yield	**Balance by Increasing**
• Substitute Ethanol for MTBE - Only Need Half As Much Ethanol for Same Oxygen Content • Remove "Light Ends" to Keep RVP Down • Remove "Heavy Ends" to Reduce T50 and T90	• Crude Oil Throughput (utilization increase) • Production and Purchase of Clean Streams (Iso-octane, alkylate) • Volume of Ethanol Used • Product Imports

Yield Losses

When MTBE is removed and ethanol is added to gasoline, the RVP increases and thus VOC emissions increase. To counter the increase, the remaining base gasoline must be adjusted to a lower RVP. For the summer blends, the RVP of either Federal reformulated gasoline blendstocks for oxygenate blending (RBOB) or CARB reformulated gasoline blendstocks for oxygenate blending (CaRBOB)[7] must be reduced by 1.3 psi. This is accomplished by removing the light materials that boil at low temperatures and therefore

[7] RBOB and CaRBOB are unfinished base blends of reformulated gasolines with properties that meet Federal and California requirements, respectively, after oxygenate is added.

have high RVPs. These materials are the C_4 and C_5 hydrocarbons.[8] Removal of these high-RVP materials is accomplished by eliminating the addition of normal butane and altering the distillation of light straight run gasoline, alkylates, and fluid catalytic cracking (FCC) gasoline in order to reduce the volume of C_4's and C_5's in these gasoline streams.

After C_4's and C_5's are reduced to achieve RVP and 5.8 percent ethanol replaces 11.2 percent MTBE, the resulting distillation properties are different. The elimination of light, high-RVP components in combination with a reduction in volume of light oxygenates cause the T50 and T90 distillation temperatures for the gasoline blend to rise (and conversely the E200 and E300 to drop). These changes in combination with less dilution of undesirable emission components require further adjustments to the base blend to meet emissions limits. This means removing some of the heavy material that boils at higher boiling temperatures from FCC gasoline or reducing the boiling range of the feed stream to the reformer, which in turn reduces the high boiling material in the reformate gasoline stream. Also, the heavy ends of FCC gasoline have high aromatics as does the heavy, high-boiling-point reformate. Thus, the shift to ethanol can result in loss of volume in three areas:

- Less oxygenate volume (moving from 11.2 to 5.8 volume percent);
- Removal of light, high-RVP volumes (C_4's and C_5's) to counter ethanol's higher RVP; and
- Removal of heavy, high-boiling-temperature volumes to counter the loss of high-RVP, low-boiling-temperature components and the net reduction in light oxygenate volume.

As discussed previously and shown in Table 3, refiners will experience an increase in toxics shifting from MTBE to ethanol. Refiners can reduce toxics by reducing benzene content, such as by adding isomerization or other benzene-reducing processes, and by reducing sulfur content. Because some refiners using MTBE have already made refining changes to reduce sulfur and benzene in their gasoline, they have very clean toxic baselines and can do little more to reduce toxics and counter the increases in toxic content when ethanol is used instead of MTBE. Those refiners will then need to reduce their production of RFG, diverting the components previously used in RFG to conventional gasoline, if their conventional gasoline can absorb the material and not exceed anti-dumping and MSAT requirements.

[8] Gasoline is a mixture of chemical compounds primarily made from hydrogen (H) and carbon (C). A compound containing only hydrogen and carbon is called a hydrocarbon. The size of these hydrocarbons is usually described by the number of carbon atoms which they contain, represented as C_4 or C_5, which means 4 carbon atoms or 5 carbon atoms respectively. Butane (C_4H_{10}) and butylenes (C_4H_8), for example, are both considered C_4.

Making up for Yield Loss

Refiners have several options to make up for the loss in volumes of summer gasoline when they switch from MTBE to ethanol. The first is simply to increase crude oil and unfinished oil throughputs, if capacity is available. While the yield of gasoline from each barrel of crude oil remains lower than before, by running more crude oil, more gasoline is produced. The economics of this choice will depend on a refiner's capacity available to increase runs and on their markets for the increased volumes of other products that would also be produced.

The second option is to increase the volume of ethanol. As discussed in Appendix B, this may not be an option for everyone due to emission constraints. For others, the economics of ethanol compared to other options will dictate the solution.

The third option will be to produce or purchase more alkylate or iso-octane. These gasoline components have very few harmful emission effects because they contain no sulfur, aromatics, or olefins, do not have high RVPs, and have good distillation profiles both from an emission and a driveability standpoint. They also are moderately high in octane. The components pass the CARB reformulated gasoline requirements as well as the Federal RFG requirements. However, MTBE is generally better in terms of distillation profile and octane, which means that, like ethanol, even alkylate and iso-octane are not "substitutes" for MTBE since a one-for-one replacement might still result in a gasoline that needed further adjustments. These are key components to producing RFG without oxygenates and they also can be used to extend the volume of RBOB. One of the uncertainties refiners face is how much alkylate or iso-octane will be available and at what price. (See Appendix C for more discussion of alkylate availability.)

Refiners and marketers may be able to import more blendstocks and finished gasoline to make up any remaining volume difference. However, availability of clean gasoline blendstocks or RFG in the future is uncertain as U.S. gasoline requirements change relative to other countries and as Europe's need for clean gasoline streams grow.[9]

The magnitude of the loss in volume of RFG gasoline production when eliminating MTBE will vary among refineries as will their solutions for making up that volume, depending on the types and fractions of gasoline components normally produced. The remainder of this discussion explores potential impacts of an MTBE ban on production of gasoline at refineries serving the East Coast. It then examines a regional supply-demand balance for 2007 and shows the impact of an MTBE ban on U.S. gasoline supply, including refinery capacity utilization levels and imports.

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[9] Energy Information Administration, "Availability of Gasoline Imports in the Short- to Mid-Term: U.S. Perspective," presented at the 2001 Annual Meeting of the National Petroleum Council, http://www.eia.doe.gov/pub/oil_gas/petroleum/presentations/2002/npra/index.html .

Illustrations of Individual Refinery Volume Losses and Gasoline Adjustments When Removing MTBE

This section develops the basis for how refiners might adjust to accommodate the loss of MTBE. Individual refinery analyses are explored that illustrate the issue and provide a basis for extrapolating to the industry. These analyses are limited to several refinery configurations, but they provide a basis to illustrate the magnitude of the volume issue.

The impact of an MTBE ban affects refiners producing Federal RFG differently than those producing CARB reformulated gasoline. California refinery impacts are discussed in Appendix B. In the Midwest, most of the RFG now being produced is made with ethanol; consequently, an MTBE ban would have no impact on this area. The largest of all reformulated fuel regions in the United States is in the Northeast, which consumes more than 40 percent of total U.S. RFG. About 54 percent of 2001 East Coast RFG demand was supplied by refineries in the Northeast, and the balance came from the Gulf Coast (28 percent) and imports (18 percent). On average, East Coast refineries produced 62 percent of their gasoline as RFG, with some refiners in the Northeast producing over 80 percent of their gasoline as RFG. Most Gulf Coast refineries produce a much smaller percentage of their gasoline as RFG.

Others have studied the refinery impacts of removing MTBE. One such study by Purvin & Gertz and Stratco (alkylation process experts)[10] analyzed the shift from MTBE to ethanol in a Gulf Coast refinery as well as a West Coast refinery (Appendix B). The configuration of the Gulf Coast refinery is typical of such facilities, but this example has the refinery producing 100 percent RFG, which is more typical of an East Coast than a Gulf Coast refinery. The cases analyzed were:

- Base – Refineries use MTBE
- II - Refineries use 7.9 percent ethanol and converts former MTBE fuel to alkylate
- III - Refineries use 8.9 percent ethanol and increases olefins from the fluid catalytic cracking unit for input to the alkylation unit
- IV - Refineries use 6.7 percent ethanol and alkylates C_5 olefins.

As shown in Table 4, the shift from MTBE to ethanol results in a decline in gasoline production of 3.4 to 6.6 percent, depending on the case, with refinery modifications made to remove C_5's from refinery streams and increase alkylate production.

EIA analyzed a number of cases for a similarly configured refinery to that used by Stratco/Purvin & Gertz. The results are summarized in Table 5. The loss of gasoline production in EIA's Case 2, when 11.2 percent MTBE was replaced with 10 percent ethanol is 12.3 percent (54.5 thousand barrels per day declining to 47.8). Cases 3 and 4 illustrate how adding alkylate to ethanol blended RFG through increased production or

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[10] Melissa Graham, Pam Pryor, Michael Sarna,"Refining Options for MTBE-Free Gasoline," Stratco Inc. and Purvin & Gertz, Inc. Paper presented at the annual NPRA meeting 2000, AM-00-53, and is available on the Stratco web site.

Table 4. Gulf Coast Refinery Cases Developed by Stratco/Purvin & Gertz

Case	Gasoline Production Pool Volume BPD	Gasoline Production Change percent	Pentane Sales BPD	Ethanol (MTBE) BPD	Isobutane Purchased BPD	Incremental Alkylate Production BPD	Process Capacity Changes*
Base	103,455		0	(10,500)	0	Base	
II	96,661	-6.6	5,706	7,626	849	+2,734	1,3,4
III	96,542	-6.7	6,250	8,631	1,338	+3,661	1,3,4
IV	99,901	-3.4	1,641	6,740	2,839	+7,993	1,2,3,4

BPD = barrels per day

*Process Capacity Notes:

1. New light straight run depentanizer
2. New fluid catalytic cracking gasoline depentanizer
3. Expand olefin treating (mercaptan removal and selective hydrogenation)
4. Expand alkylation

Source: "Refining Options for MTBE-Free Gasoline" NPRA AM00-53, presented at NPRA's Annual Meeting in 2000. http://www.stratco.com/pdf/RefiningOptionsPaper.pdf .

purchases helps to recover some of the volumes lost. In Case 3 refinery alkylate production was increased. When alkylate production is increased in Case 3 over Case 2, reformate production can also be increased, since the additional alkylate helps to dilute the aromatics content of the reformate and alkylate's lighter, low boiling temperature components allow the addition of some of reformate's heavier, higher boiling temperature volumes without distorting the distillation profile significantly. Case 4 illustrates that alkylate and ethanol cannot simply substitute for one another. It shows that when ethanol is reduced from 10 percent to 5.8 percent, and alkylate replaces that ethanol, the reformate heavy ends cannot stay at the volumes of Case 3 due alkylate's distillation properties relative to ethanol's. Alkylate boils at higher temperatures than ethanol and changes the mixture's distillation profile enough to prevent being able to add more reformate. Thus, a volume loss occurs in going from Case 3 to Case 4, but depending on the relative prices of alkylate and ethanol, Case 4 could be preferred.

The gasoline production process changes in the EIA cases were similar to those in the Stratco/Purvin & Gertz cases, but the light and heavy component adjustments were different. The EIA blends required greater removal of heavy ends from FCC gasoline and reformate to achieve the required VOC target. The important point to understand is that while refiners will generally face the same types of problems in eliminating MTBE, the impacts on their gasoline production will vary based on the types of process units in the refinery, the way those units are operated, the types of crude oil they use, and the fraction of RFG in their total gasoline production. This example demonstrates how much the volume loss may differ at the individual refinery level.

Table 5. MTBE-Ban Case Analysis for RFG Production – Federal RFG Producing Refinery

	Base Case		Case 2		Case 3		Case 4	
	RFG Production with MTBE		MTBE Ban – Ethanol at 10%		MTBE Ban – Ethanol at 10% + Increased Alkylate Production		MTBE Ban – Ethanol at 5.8% + Purchase Alkylate	
Gasoline Blend Components Based on 100MB/D Refinery:	**Volume (MB/D)**	**Vol %**	**Volume (MB/D)**	**Vol %**	**Volume (MB/D)**	**Vol %**	**Volume (MB/D)**	**Vol %**
Production								
LSR & Other C_5's	7.3	13.4	3.8	7.8	3.8	7.2	3.8	7.4
Isomerate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Reformate	18.3	33.5	16.4	34.4	18.0	34.5	16.1	31.8
FCC Gasoline	15.7	28.8	15.7	32.8	15.7	30.1	15.3	30.3
Alkylate	7.1	13.1	7.1	14.9	9.5	18.2	9.5	18.8
n-Butane	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1
Refinery Production	48.4		43.0		47.0		44.6	
Purchases								
MTBE	6.1	11.2	0.0	0.0	0.0	0.0	0.0	0.0
Ethanol	0.0	0.0	4.8	10.0	5.2	10.0	2.9	5.8
C_3 Alkylate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C_4 Alkylate	0.0	0.0	0.0	0.0	0.0	0.0	2.9	5.7
Total Purchases	6.1		4.8		5.2		5.8	
Total Gasoline Production	54.5	100.0	47.8	100.0	52.2	100.0	50.4	100.0
Properties								
Octane: (R+M)/2	87.2		87.8		88.1		87.4	
RVP: psi	6.7		6.5		6.4		6.5	
Benzene: vol%	0.56		0.63		0.58		0.60	
Aromatics: vol%	25.5		26.7		26.3		24.9	
Olefins: vol%	9.0		10.2		9.4		9.3	
Sulfur: ppm	115.1		131.2		120.2		124.0	
E200: vol%	47.4		43.9		42.9		40.5	
E300: vol%	79.2		79.2		78.5		80.3	
Summary RFG Requirements	**Changes from Industry Baseline [a]**	**Federal Target [b]**	**Changes from Industry Baseline [a]**	**Federal Target [b]**	**Changes from Industry Baseline [a]**	**Federal Target [b]**	**Changes from Industry Baseline [a]**	**Federal Target [b]**
VOC: % Reduction	-25.9	≥25.9	-25.9	≥25.9	-25.9	≥25.9	-25.9	≥25.9
Toxics: % Reduction	-32.0	≥20.0	-26.3	≥20.0	-27.2	≥20.0	-28.2	≥20.0
NO_x: % Reduction	-8.8	≥5.5	-7.9	≥5.5	-8.8	≥5.5	-9.1	≥5.5
Benzene: vol %	0.56	≤1.0	0.63	≤1.0	0.58	≤1.0	0.60	≤1.0

[a] Emission reductions and benzene content of illustrative fuel for comparison with Federal requirements.
[b] Federal reformulated gasoline required emission reductions and benzene content from industry baseline.

Definition of abbreviations and technical terms:

LSR = light straight run;
FCC = fluid catalytic cracking;
ppm = parts per million;
psi = pounds per square inch;
vol% = volume percent;
VOC = volatile organic compounds;
POM = polycyclic organic materials;
MB/D = thousand barrels per day
mg/mi = milligrams per mile;
MTBE = methyl tertiary butyl ether;
ETBE = ethyl tertiary butyl ether;
TAME = tertiary amyl methyl ether;
RVP = Reid vapor pressure.

Source: Energy Information Administration

Refineries producing Federal RFG are subject to Mobile Source Air Toxics Rule (MSAT). (MSAT is also discussed in the response to Factor 5.) Cases 5-8 in Table 6 illustrate steps refiners can take to meet MSAT as they remove MTBE. The toxics reduction in Cases 2, 3, and 4, when replacing MTBE with ethanol, are less than in the Base Case and do not meet MSAT requirements, since their toxics emissions are reduced less than in their historical baseline of 32 percent shown in the Base Case containing MTBE. Table 6 shows steps refiners may take to achieve the 32-percent toxics reduction in the Base Case containing MTBE. The main avenues to reducing toxics emission are by sulfur and benzene reduction through processes like isomerization and benzene extraction.

Case 5 (Table 6) takes Case 3 (Table 5) and isomerizes the light straight run cut, which reduces the benzene from 0.58 percent to 0.30 percent. Toxics reduction increases from 27.2 percent to 30.0 percent, but is still less than the 32-percent reduction of the MTBE Base Case. Case 6 includes the additional step of desulfurizing all the FCC gasoline, which reduces gasoline sulfur content from 122 ppm to 12 ppm. As a result, the complex model estimates that exhaust benzene will decline and that total toxics reduction is 32 percent, equal to the reduction of the MTBE Base Case. In Case 7, additional alkylate is purchased to restore volumes to those of the Base Case while achieving emissions targets and MSAT. In Case 8, MTBE is replaced with alkylate rather than ethanol. Production from refinery streams is higher in Case 8 than in Case 7 where ethanol was used, but the pool octane in Case 8 is less than with ethanol.

Table 6. Meeting MSAT: MTBE-Ban Case Analysis for RFG Production – Federal RFG Producing Refinery

	Case 5		Case 6		Case 7		Case 8	
	Case 3 + Isomerization		Case 5 + DeSulfurization		Case 7 + Alkylate to Restore Volumes		Full Volumes – No Ethanol	
Gasoline Blend Components Based on 100MB/D Refinery: MB/D	**Volume (MB/D)**	**Vol %**	**Volume (MB/D)**	**Vol %**	**Volume (MB/D)**	**Vol %**	**Volume (MB/D)**	**Vol %**
Production								
LSR & Other C_5's	0.0	0.0	0.0	0.0	0.5	0.9	3.6	6.5
Isomerate	3.6	7.0	3.6	6.9	3.6	6.6	3.6	6.6
Reformate	17.7	34.3	18.4	35.0	18.5	33.9	18.1	33.2
FCC Gasoline	15.5	30.1	15.7	29.9	15.7	28.8	15.7	28.8
Alkylate	9.5	18.5	9.5	18.1	9.5	17.5	9.5	17.4
n-Butane	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1
Refinery Production	46.3		47.2		47.8		50.5	
Purchases								
MTBE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ethanol	5.1	10.0	5.2	10.0	5.4	10.0	0.0	0.0
C_3 Alkylate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C_4 Alkylate	0.0	0.0	0.0	0.0	1.2	2.3	4.1	7.4
Total Purchases	5.1		5.2		6.7		4.1	
Total Gasoline Production	51.4	100.0	52.4	100.0	54.5	100.0	54.5	100.0
Properties								
Octane: (R+M)/2	90.1		90.0		90.0		86.9	
RVP: psi	6.4		6.5		6.6		6.4	
Benzene: vol%	0.30		0.29		0.28		0.28	
Aromatics: vol%	26.0		26.2		25.3		24.9	
Olefins: vol%	9.3		8.2		7.9		7.9	
Sulfur:ppm	122		11.9		11.5		11.4	
E200: vol%	42		42.0		42.3		39.3	
E300: vol%	79		78.1		78.6		78.8	
Summary RFG Requirements	**Changes from Industry Baseline [a]**	**Federal Target [b]**	**Changes from Industry Baseline [a]**	**Federal Target [b]**	**Changes from Industry Baseline [a]**	**Federal Target [b]**	**Changes from Industry Baseline [a]**	**Federal Target [b]**
VOC: % Reduction	-25.9	≥25.9	-26.3	≥25.9	-25.9	≥25.9	-25.9	≥25.9
Toxics: % Reduction	-30.0	≥20.0	-32.0	≥20.0	-32.6	≥20.0	-32.3	≥20.0
NO_x: % Reduction	-8.9	≥5.5	-14.1	≥5.5	-14.4	≥5.5	-14.4	≥5.5
Benzene: vol %	0.30	≤1.0	0.29	≤1.0	0.28	≤1.0	0.28	≤1.0

[a] Emission reductions and benzene content of illustrative fuel for comparison with Federal requirements.
[b] Federal reformulated gasoline required emission reductions and benzene content from industry baseline.

Definition of abbreviations and technical terms:

LSR = light straight run;
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POM = polycyclic organic materials;
MB/D = thousand barrels per day
mg/mi = milligrams per mile;
MTBE = methyl tertiary butyl ether;
ETBE = ethyl tertiary butyl ether;
TAME = tertiary amyl methyl ether;
RVP = Reid vapor pressure.

Source: Energy Information Administration

In the illustrative cases of Table 6, it was possible for the refinery to achieve the same level of toxics reduction after eliminating MTBE with investments for both isomerization and gasoline desulfurization. Because the example refinery was moderately clean (clearly above average overcompliance on toxics), the economic burden in meeting MSAT was greater than if the refinery had started with a baseline toxics reduction in the low- to mid-20-percent range. But the situation would have been even more challenging if the refinery already had isomerization or a sub-100 ppm sulfur level. In fact, it may have been impossible to achieve the toxics reduction level that was established during a baseline period when MTBE was used. The result of the combination of MTBE bans for the Northeast and MSAT is to create widely varying economic costs among refineries, with the situation that cleaner refiners would face the larger cost burden. The result could be the loss of significant gasoline production for the Northeast should some key refiners be unable to make changes to achieve the MSAT baseline established while using MTBE. This could leave the Northeast with no clear options for alternative supply of RFG in the short- to mid-term.

U.S. Aggregate Analysis

This section describes the potential impact on supply of a total U.S. ban on the use of MTBE in gasoline, and describes the supply uncertainties associated with those transition periods. The year 2007 was selected because it represents the start of the proposed Federal ban and illustrates the cumulative gasoline productive capacity supply losses that are expected to occur beginning with the State bans in 2004 and culminating with the Federal ban in 2007. While spreading the transition over several years could ease some of the transition supply uncertainties, transition hurdles remain for the East Coast after the transition in 2004 is finished. This analysis illustrates why transitions to MTBE bans have potential for initial market imbalances and price volatility.

This analysis studies the supply/demand pressures that develop to reach a balanced market. As seen during the transition to Phase II RFG in the Midwest in 2000, actual shortages can occur initially as the market sorts itself out prior to achieving equilibrium. But eventually an equilibrium condition is reached where new supply sources are found and price volatility subsides. The market and regulatory uncertainties, magnitude, and complexity of the transition associated with the 2004 MTBE ban are greater than the uncertainties and changes associated with the Midwest Phase II RFG transition.

The MTBE ban affects production of Federal and California reformulated gasolines, which are the primary gasolines using MTBE today. Volume losses in these fuels are much more difficult to make up than volume losses in conventional gasoline, since conventional gasoline is easier to produce and more refineries can supply it.

This study analyzes the U.S. gasoline supply-demand situation for the year 2007 by developing comparison cases with no MTBE bans and with a total ban of MTBE in 2007.[11] The analysis highlights the changes that need to occur to reach the ban. In 2004, 45 percent of the nation's MTBE-blended RFG is scheduled for State MTBE bans. These States will face the transition supply issues outlined in this analysis, although total volumes involved will be less.

Two scenarios are developed to demonstrate the varying role domestic refineries may play in supplying U.S. demand in the future. The first is a scenario in which capacity grows at rates seen since 1995 (High Capacity Scenario). This capacity scenario has domestic refinery capacity growth keeping pace with projected demand growth. The second scenario (Low Capacity Scenario) has capacity growth slowing.[12] This latter scenario was used in the analysis of Factor 2.

In each scenario, the analysis is done at a Petroleum Administration for Defense District (PADD) level (Appendix D). Within a given scenario, demand and capacity are the same whether or not a Federal MTBE ban is enacted. The ability of that same capacity to meet demand with and without the ban provides a means of illustrating the volume impacts of losing MTBE. While capacity is the same with or without MTBE, refinery utilization can be increased in the MTBE-Ban Case to increase gasoline production.

[11] The results would be similar for the 87-percent-ban case considered in Factor 2, where 13% of RFG is allowed to continue being produced using MTBE which is assumed to result from the MTBE waiver provision of the proposed Bill. While the U.S. RFG volume losses in Tables 12 and 16 would be slightly less for this case, the major transition issues associated with RFG supply to the East and West Coasts do not reduce the hurdles.

[12] Neither scenario is meant to be an upper or lower bound.

For both scenarios, gasoline demand is projected to grow at 1.8 percent per year through 2007, which is consistent with average annual historical growth rates during the last decade and the demand growth rates projected in the analysis for Factor 2. Regional patterns vary within this national average, but also follow historical trends (Table 7).

The differences in capacity for the two scenarios are shown in Table 8. Capacity in the High Capacity Scenario keeps pace with demand growth during this period. The capacity in the Low Capacity Scenario declines in PADD 1, stays flat in PADD 5 and increases in PADDs 2, 3, and 4 in aggregate. The capacity increase in this scenario is 0.9 million barrels per day less than in the High Capacity Scenario. The Low Capacity Scenario requires higher import volumes than the High Capacity Scenario to meet demand growth.

Table 7. Demand Projections (Thousand Barrels Per Day)

	Gasoline Demand			Change 2000-2007
	2000	2001	2007	
PADD 1	2,988	3,045	3,407	419
PADD 2	2,437	2,451	2,703	266
PADD 3	1,292	1,345	1,480	188
PADD 4	275	271	309	34
PADD 5	1,479	1,498	1,666	187
Total	8,471	8,610	9,564	1,093

Source: Energy Information Administration

Table 8. Scenario Capacity Comparison (Million Barrels Per Calendar Day)

	History	High Capacity		Low Capacity	
	2000	2007	Change	2007	Change
PADD 1	1.7	1.9	0.2	1.6	-0.1
PADDs 2-4	11.7	13.2	1.5	13.0	1.3
PADD 5	3.1	3.5	0.4	3.1	0.0
Total	16.6	18.6	2.0	17.7	1.1

Source: High Capacity: Energy Information Administration, "Availability of Gasoline Imports in the Short- to Mid-Term: U.S. Perspective," presented at the 2001 Annual Meeting of the National Petroleum Council, http://www.eia.doe.gov/pub/oil_gas/petroleum/presentations/2002/npra/index.html; Low Capacity: EIA No State Ban Run ENsXmXoX.d082302a

For each scenario, the effects of an MTBE ban are analyzed as follows:

- The first step develops a base case forecast (No-Ban Case) of supply and demand by PADD under the assumption that MTBE use continues through the year 2007.
- The gap or shortfall due to loss of MTBE is established next. The changes from the No-Ban Case that an MTBE ban would cause are quantified, including: estimates of the gasoline production losses due to losing MTBE and substituting less ethanol;

removing additional light and heavy components to balance the gasoline blend after the changes; and the addition of extra alkylate due to the conversion of some MTBE production facilities.

- The last step balances the gap with increased crude oil throughputs and imports in both cases.

High Capacity Scenario

No-Ban Case

In order to keep the presentation simple, this case and the subsequent MTBE-Ban Case do not incorporate price dynamics into the demand or capacity projections. That is, both cases within the scenario serve the same demand with the same refinery capacity. This is consistent with focusing on supply impacts during the transition period of a ban. In the longer term, supply adjustments could be made.

The capacity in the High Capacity Scenario is based on a refinery-by-refinery analysis of historical capacity changes. EIA analyzed refinery closures and expansions that occurred over the past 2 decades, relating the changes to regional location, refinery size and type of ownership to develop a regional projection between now and 2007.[13] Regional differences provided clues to understanding past refinery expansion and potential future expansion. Each region has different marginal competitors and different margins, both of which influence expansion. It was observed that different ownership types are following different refinery strategies. Those strategies are assumed to continue to be pursued. It was also noted that smaller refineries are more exposed to potential shutdowns than larger refineries. Again, because many small refineries still exist that are less competitive than other refineries, such shutdowns are assumed to continue for some time. However, the rate of shutdowns has slowed and the size of shutdowns is up slightly. The marginally economic refinery size, which was once about 20 thousand barrels per day, has grown to about 50 thousand barrels per day.

Table 9 below shows historic and projected changes for U.S. refinery capacity, taking into account refinery closures and expansions. Small refineries have been the main facilities that have closed, while larger refineries have expanded. This table summarizes the shutdowns and growth of refineries remaining in operation. The capacity shutdown rate has slowed, although shutdowns are expected to continue in the future as refineries with poor competitive cost structures and with disadvantages of economies of scale face new facility investments both to meet new fuel specifications and to comply with refinery

[13] Energy Information Administration, "Availability of Gasoline Imports in the Short- to Mid-Term: U.S. Perspective," presented at the 2001 Annual Meeting of the National Petroleum Council, http://www.eia.doe.gov/pub/oil_gas/petroleum/presentations/2002/npra/index.html and "Petroleum Outlook: Increased Inter-PADD Movements Expected," presented at API Annual Pipeline Conference, Dallas, Texas, April 2002, http://www.eia.doe.gov/pub/oil_gas/petroleum/presentations/2002/api/index.html .

emissions requirements. A critical uncertainty over the next 5 years is whether the high capital demands placed on refineries to meet new fuel specifications will accelerate the refinery closure rate.

Table 9. U.S. Refinery Capacity Closures and Growth

Time Period	Annual Average Shutdown of Capacity (MB/CD)	Annual Growth of Continuously Operating Capacity (Percent)
1990-1994	139	0.5
1995-1999	96	2.0
2000-2007	60	2.0

MB/CD – Thousand barrels per calendar day
Source: Energy Information Administration, "Availability of Gasoline Imports in the Short- to Mid-Term: U.S. Perspective," presented at the 2001 Annual Meeting of the National Petroleum Council, http://www.eia.doe.gov/pub/oil_gas/petroleum/presentations/2002/npra/index.html

Most U.S. refineries that have continued to operate over the past 15 years have expanded their capacity. As Table 9 shows, capacity growth increased in the 1995-1999 period as demand and capacity utilization increased and margins improved moderately. The growth rate is expected to continue through 2007. However, growth rates are not projected to be constant, due to fluctuations in margins and the timing of clean fuel requirements.

Since 1990, refinery growth has varied by size and by region of the country, but growth by ownership category has shown the greatest variation. Growth was assessed by ownership categories of major integrated companies, independents, and refineries with major ownership by foreign crude-oil producing countries (e.g., Venezuela, Mexico, and Saudi Arabia).

- Independents have expanded the facilities they own at the fastest rate (3-5 percent per year) and also made extensive acquisitions. The existence of independents depends on running their businesses profitably, and they seem to be pursuing a strategy of growth both in market share and in keeping up with U.S. needs.

- The majors have spun off refineries, many of which were acquired by independents. With the exception of Exxon/Mobil, the majors have expanded their refineries very little. The majors seem to be concentrating on crude oil production, using refining to maintain crude oil profitability.

- The refineries owned partially or entirely by crude-oil producing countries have not increased distillation capacity much (which is one measure of capacity) but have made changes to run a larger fraction of their heavy crude oils, which frequently involved adding coking, desulfurization, and other bottom-of-the-barrel facilities. These refiners need outlets for their very heavy crude oils and will undoubtedly continue this strategy for some time.

The net increase in capacity, when combining closures and expansions, averaged about 1.7 percent per year, or about the same growth rate as expected for gasoline demand. Table 10 shows that from 2000 to 2007, U.S. refinery capacity is estimated to increase by roughly 2 million barrels per day and gasoline by roughly 1 million barrels per day. Since gasoline production uses about 50 percent of crude oil input to refineries, refining gasoline production capability increases to keep pace with demand growth.

Table 10. U.S. Demand and High Capacity Scenario Refinery Capacity Changes, 2000-2007 (Thousand Barrels per Day)

	Gasoline Demand			Refining Capacity		
	2000	2007	Change	2000	2007	Change
PADD 1	2,988	3,407	419	1,704	1,869	164
PADD 2	2,437	2,703	266	3,620	3,981	361
PADD 3	1,292	1,480	188	7,553	8,613	1,060
PADD 4	275	309	34	541	577	36
PADD 5	1,479	1,666	187	3,095	3,493	398
Total	8,471	9,564	1,093	16,512	18,532	2,020

Source: Energy Information Administration

Putting this capacity together with demand, the balance in the No-Ban Case is shown in Table 11.

Table 11. High Capacity Scenario No MTBE Ban Supply-Demand Balance

	Refining Capacity	Crude & Unfinished Oils Inputs	Utilization	Gasoline Demand	Gasoline Production	Net Imports
	MB/D	MB/D	Percent	MB/D	MB/D	MB/D
2000	16,512	15,526	94	8,471	8,185	282
2007	18,532	17,431	94	9,564	9,168	396
Increase	2,020	1,905	0	1,093	983	114

MB/D = thousand barrels per day
Totals may not equal the sum of the components due to independent rounding.
Source: Energy Information Administration

Impact of an MTBE Ban Under the High Capacity Scenario

Using the individual refinery case studies described previously, this subsection develops aggregate impacts of an MTBE ban on the No-Ban Case. Since MTBE is used primarily in reformulated gasoline, the volume loss from the ban mainly affects reformulated gasoline. The analysis investigates the supply losses from eliminating 100 percent of MTBE. This ban, the MSAT requirement, and other clean fuel specifications result in a net loss of reformulated gasoline production capability as discussed earlier. Also MSAT, antidumping, and other requirements keep light, high-RVP components that must be removed from reformulated gasoline from being added to conventional gasoline during the peak summer gasoline season. This means that fewer barrels of gasoline are yielded from the same barrels of crude oil. Generally, this will result in higher levels of capacity utilization and a greater need for gasoline imports. Since many of today's gasoline imports are RFG and blending components for RFG coming into the large RFG-consuming region of the Northeast, future gasoline imports could be expected to be similar. The supply-demand balance displays show the need for imports to meet demand.

In order to analyze these changes, two steps were taken to translate these impacts to a regional supply-demand balance. First, the refinery production volume loss that would occur with the MTBE removal was assessed before adjusting utilization and imports to balance supply with demand. The results of the volume losses that must be offset are shown in Table 12. The second step is balancing the volume loss with higher refinery capacity utilization and imports, as described in the next subsection.

Table 12 defines the volume shortfall an MTBE ban would cause in this scenario. The estimates in Table 12 are based on EIA's individual refinery analyses using a gasoline blending spreadsheet model, work done by and for the California Energy Commission, the Stratco/Purvin & Gertz paper, and information obtained in discussions with refiners. The volume impacts of an MTBE ban will vary among facilities. Estimating volume impacts for each refinery would improve the estimates of Table 12, but lack of detailed refinery information and the time available to prepare this analysis precluded such an approach.

The MTBE ban impacts shown in Table 12 are broken down by type of impact for each region. For PADDs 1 through 5, a total of 306 thousand barrels per day of MTBE, which would have been used in 2007 in the No-MTBE Ban case, will be lost from the volume of gasoline produced in 2007. In place of the MTBE, an estimated 151 thousand barrels per day of ethanol will be added. Because the ethanol increases the vapor pressure of gasoline, other light, low-boiling-temperature components (C_4 and C_5 hydrocarbons) will be removed from RFG blends to meet the VOC requirements for the summer-grade RFG. On an annual basis, the light ends reduction is estimated to be 113 thousand barrels per day. The combination of less ethanol being used than MTBE and the removal of the light ends to meet RVP will result in an increase in distillation temperatures for the blend. Also, there will be less dilution of the heavier components, which have higher aromatic contents. As a result, some refineries will have to remove heavy, high-boiling-point material from the FCC gasoline and/or reformate to move the distillation profile down.

The heavy-ends reduction is estimated to be 40 thousand barrels per day. At this point in the balance, the added ethanol (151 thousand barrels per day) is offset by the removal of light and heavy ends (-153 thousand barrels per day).

More alkylate is expected to be available in the MTBE-Ban Case to increase volume. When MTBE is banned, there will remain feedstock and production facilities at refineries' MTBE units and at some large-scale commercial MTBE plants. It is assumed that the iso-butylene feedstock that has been fed to MTBE units at refineries will be used as alkylate feed, adding 107 thousand barrels per day of alkylate for RFG production. Based on the economics of conversion of commercial MTBE facilities to alkylate or iso-

Table 12. High Capacity Scenario Changes(1) from the No-Ban Case When MTBE is Removed (Thousand Barrels Per Day)

	PADD 1	PADD 2	PADD 3	PADD 5	Total U.S.
Loss of MTBE Volumes	-100	0	-93	-113	-306
Addition of Ethanol to RFG(2)	75	0	18	58	151
Reduction in Light Ends for RVP	-25	0	-38	-50	-113
Reduction of Heavy Ends for Distillation Points	-14	0	-9	-17	-40
Refinery Increased Alkylate Production	9	10	71	17	107
Commercial Alkylate or Iso-Octane Production	0	0	25	10	35
Added Ethanol in Conventional	0	-20	0	0	-20
Total	-55	-10	-26	-95	-186

(1) These estimates do not take into consideration additional volume losses due to MSAT constraints on refiners switching from MTBE to ethanol.
(2) The energy content of the gasoline produced for PADDs 1,3, and 5 are approximately the same before and after the MTBE ban because even though ethanol has a lower energy content than MTBE (76 vs. 92 thousand Btu's), 5.8 percent ethanol is being used in the estimate in place of 11.2 percent MTBE. Thus no volume adjustment for energy content differences is needed in this table.
$115 = 0.112*93.5 + .888*117.7$ and
$115 = 0.058*76 + 0.942*117.7$.
Totals may not equal the sum of the components due to independent rounding.
Source: Energy Information Administration

octane production and discussions with facility operators, only a small fraction of the commercial capacity will likely be converted. A total of 25 thousand barrels per day on the Gulf Coast and 10 thousand barrels per day in PADD 5, which represents anticipated iso-octane imports from an existing Canadian facility, are projected.

The “added ethanol in conventional” line in Table 12 is a volume difference that arose when ethanol production was assumed to shift from conventional gasoline to RFG in the early years of an MTBE ban. The elimination of MTBE will mean a dramatic increase in ethanol use. The California Energy Commission (CEC) is projecting that U.S. ethanol production capacity will increase by 60 percent between 2002 and 2005.[14] EIA is projecting that ethanol use for gasoline will almost double by 2007 to reach over 250 thousand barrels per day. This scenario estimates a need for 151 thousand barrels per day of increased ethanol use in Federal RFG and California reformulated gasoline in 2007, most of which will come from new production. The use of ethanol in conventional gasoline would then be 20 thousand barrels per day lower because of the ethanol use in RFG and in California reformulated gasoline.

In summary, Table 12 indicates that, if MTBE and other ether use is eliminated in 2007, about 166 thousand barrels per day of reformulated gasoline supply and 20 thousand barrels per day of conventional gasoline supply will still need to be produced or imported. While PADD-level volume impacts were estimated because of the need to adjust for VOC emission requirements when switching from MTBE to ethanol, MSAT effects were not included because of lack of information available to EIA. In no way should this be taken to mean that MSAT effects are insignificant.

Comparison of No-Ban and MTBE Ban Results Under the High Capacity Scenario

This subsection displays the supply-demand balances by PADD for both the No-Ban and MTBE-Ban Cases. It compares production and import levels to illustrate how, after utilization is increased, imports would increase to fill the remaining gap.

Table 13 shows the changes from 2000 to 2007 that occur in the No-Ban Case. The table shows that most of the increase in gasoline demand is met by an increase of 983 thousand barrels per day of refinery gasoline production and an increase of 114 thousand barrels per day of finished gasoline imports. The production increase is achieved through increases in capacity and with refinery capacity utilization at about the same level as it was in 2000.

Regionally, PADD 3 supplies a large increase in volumes to PADD 1, which helps to reduce the need for increasing imports on the East Coast as demand increases.

For the MTBE-Ban Case, refinery utilization was increased 1.5 percent and imports were also increased in order to fill the 186 thousand barrel per day gap that occurred. Table 14 shows the changes that would occur from 2000 under these circumstances.

In the MTBE-Ban Case, refinery capacity and demand remain the same as in the No-Ban Case. To help supply the 186-thousand-barrel-per-day shortfall, higher utilization resulted in crude oil and unfinished oils inputs increasing from 1,905 to 2,183 thousand

[14]California Energy Commission, “U.S. Ethanol Industry Production Capacity Outlook,” Update of 2001 Survey Results, July 18, 2002.

Table 13. High Capacity Scenario No-Ban Case
Increases in Gasoline Supply & /Demand Between 2000 & 2007

	Refinery Capacity	Crude & Unfinished Oils Inputs	Gasoline Demand	Gasoline Production	Net Receipts	Net Finished Imports	Blending Component Imports
	MB/D	MB/D	MB/D	MB/D	MB/D	MB/D	MB/D
PADD 1	164	130	419	90	242	77	1
PADD 2	361	363	266	239	34	0	0
PADD 3	1060	1043	188	511	-344	25	0
PADD 4	36	19	34	2	33	0	0
PADD 5	398	350	187	141	33	12	0
Total U.S.	2020	1,905	1,093	983	0	114	1

MB/D = thousand barrels per day
Unfinished Oils do not include gasoline blendstocks such as alkylate.
Net Receipts are flows of product from other regions.
Totals may not equal the sum of the components due to independent rounding.
Source: Energy Information Administration

Table 14. High Capacity Scenario MTBE-Ban Case
Increases in Gasoline Supply & Demand Between 2000 & 2007

	Refinery Capacity	Crude & Unfinished Oils Inputs	Gasoline Demand	Gasoline Production		Net Receipts	Net Finished Imports	Blending Component Imports
				Refinery	Blender			
	MB/D	MB/D	MB/D	MB/D	MB/D	MB/D	MB/D	MB/D
PADD 1	164	158	419	40	333	220	-183	299
PADD 2	361	423	266	238	0	35	0	0
PADD 3	1,060	1,172	188	545	0	-378	25	0
PADD 4	36	28	34	14	0	21		0
PADD 5	398	403	187	74	0	100	12	0
Total	2,020	2,183	1,093	910	333	0	-146	299

MB/D – Thousand barrels per day
Unfinished Oils do not include gasoline blendstocks such as alkylate.
Gasoline Production includes production from blenders. They are only broken out for PADD 1, where large changes would be expected. The large increase in PADD 1 is due to a shift from finished RFG imports to RBOB imports, which blenders then use to produce finished RFG.
Net Receipts are flows of product from other regions.
PADD 2 gasoline production declined slightly in the MTBE-Ban Case from the No-Ban case due to diversion of conventional gasoline ethanol in PADD 2 to RFG in PADDs 1 and 5.
Totals may not equal the sum of the components due to independent rounding.
Source: Energy Information Administration

barrels per day. However, because of the yield loss, gasoline production declined 73 thousand barrels per day relative to the No-Ban Case.

In the MTBE-Ban Case, imports shift from RFG finished gasoline to RBOB, which is accounted for in blending component imports. Thus, finished imports fall, but blending component imports rise. The net increase is 38 thousand barrels per day over the No-Ban

Case. Since ethanol is being added in the United States to RBOB imports, the import increase did not have to match the shortfall in production from the No-Ban Case.[15]

PADD 5's shortfall under an MTBE ban will require an additional 67 thousand barrels per day in net receipts of California-reformulated-gasoline-quality components. The magnitude of such high quality inflows to California has not been seen historically. PADD 3 is assumed to supply these volumes to PADD 5, reducing supply to PADD 1. This, in combination with the reduced refinery production in PADD 1 combine to create the need for higher product imports into the region.

The MTBE-Ban Case pushes the supply system to a high level. Annual average refinery capacity utilization is in the 94-95-percent range. With capacity utilization at 95 percent on an annual basis, during the summer peak demand months it will be at or slightly over 100 percent (calendar day basis) to meet demand. Utilization was at those levels in the summer of 1997 when gasoline markets could not respond to unexpected outages and prices surged.

Greater ethanol use than assumed in the MTBE-Ban Case in East and Gulf Coast areas could also potentially add to the volumes of reformulated gasoline, but such increases would take away from ethanol being used in conventional gasoline. California refineries are limited to about 5.8 volume percent ethanol due to emission constraints, but refiners producing Federal RFG are not so constrained.

Additional supply volumes will not be easy to obtain. The MTBE-Ban Case assumes major supply gaps on the East and West Coasts will be filled. In particular, East Coast refiners face not only a decline in gasoline production capability due to loss of MTBE, but also potential additional declines in volumes due to MSAT limitations. West Coast suppliers need extra volumes of gasoline blendstocks that meet California reformulated gasoline specifications from outside of the California refinery system. This analysis does not take into consideration MSAT impacts. It also assumes that California is able to find the required extra volumes of its very clean fuel from shipments from the Gulf Coast and that East Coast requirements are met by RBOB imports. Whether Gulf Coast refiners or import refineries will have the supply available during a transition is uncertain.

Low Capacity Scenario

The Low Capacity Scenario uses the same capacity volumes as were used in EIA's response to Factor 2. As illustrated below, the Low Capacity Scenario has a need for higher imports in 2007 than the High Capacity Scenario before removing MTBE. Capacity utilization was increased by 1.5 percent in this scenario, as it was in the High Capacity Scenario, to help meet lost volumes.

[15] The increase in blender production of 333 thousand barrels per day is not just due to imported RBOB. It also contains the RFG produced from RBOB transported from the Gulf Coast.

No-Ban Case

As in the High Capacity Scenario, the No-Ban Case assumes MTBE continues to be used in all RFG areas that were using it in 2000. For purposes of this analysis, the aggregate capacity in PADDs 2-4 was separated into individual PADDs. The growth rates were based on historical trends of shutdowns and expansions similar to those used in the High Capacity Scenario. The individual PADD capacities are shown in Table 15. With distillation capacity increasing 1.2 million barrels per day, gasoline production capability would increase by about half that amount, falling short of the increase in gasoline demand of over 1 million barrels per day. This scenario has a reduction in capacity in PADD 1 and a small increase in PADD 5.

Table 15. U.S. Demand and Low Capacity Scenario Refinery Capacity Changes, 2000-2007 (Thousand Barrels Per Day)

	Gasoline Demand			Refining Capacity		
	2000	2007	Change	2000	2007	Change
PADD 1	2,988	3,407	419	1,704	1,570	-134
PADD 2	2,437	2,703	266	3,620	4,040	420
PADD 3	1,292	1,480	188	7,553	8,458	905
PADD 4	275	309	34	541	547	6
PADD 5	1,479	1,666	187	3,095	3,116	21
Total	8,471	9,564	1,093	16,512	17,731	1,219

Totals may not equal the sum of the components due to independent rounding.
Source: Energy Information Administration

Impact of an MTBE Ban Under Low Capacity Scenario

As in the High Capacity Scenario, the first step is to calculate the volume loss that would occur with removal of MTBE, before doing the regional supply-demand balance by adjusting utilization and imports. The results of the volume loss that must be offset are shown in Table 16. The second step is balancing the volume loss with higher refinery capacity utilization and imports, as described in the next subsection.

As in the High Capacity Scenario, a total of 306 thousand barrels per day of MTBE, which would have been used in 2007 in the No-Ban Case, will be lost from the volume of gasoline produced in 2007. In place of the MTBE, an estimated 151 thousand barrels per day of ethanol will be added. The light and heavy ends that must be removed to accommodate ethanol’s physical properties are slightly lower in the Low Capacity Scenario because refinery capacity and gasoline production are less.

Table 16 indicates that in 2007, about 160 thousand barrels per day of reformulated gasoline supply and 20 thousand barrels per day of conventional gasoline supply will still need to be served by additional means. The loss is similar to that of the High Capacity Scenario because a large fraction of RFG will still be produced by U.S. refineries.

Comparison of Scenarios With No-Ban and MTBE-Ban Cases

In order to fill the shortfall shown in Table 16, refinery capacity utilization and imports are adjusted to develop regional balances. The major differences that occur between the High Capacity Scenario and the Low Capacity Scenario are in PADDs 1 and 5. In the High Capacity Scenario, both PADDs 1 and 5 meet demand growth by increasing capacity and receiving extra shipments of product from the Gulf Coast. PADD 1 also requires a small increase in imports. In the Low Capacity Scenario, PADD 5 needs increasing California reformulated gasoline from the Gulf Coast to meet demand. Unlike the High Capacity Scenario, PADD 1 must meet its demand growth from imports, since PADD 3's production increases are being diverted mainly to PADD 5.

Table 17 shows the changes from 2000 to 2007 that occur for both Scenarios in PADD 1. In the High Capacity Scenario of Table 17, the import requirement for PADD 1 grows from 596 thousand barrels per day in 2000 to 674 thousand barrels per day in the No-Ban Case and 712 thousand barrels per day in the MTBE-Ban Case. For the Low Capacity Scenario, the growth in PADD 1 imports from 2000 is greater, increasing to 1,045 thousand barrels per day in the No-Ban Case and 1,055 with an MTBE ban.

Table 16. Low Capacity Scenario Changes(1) from the No-Ban Case When MTBE is Removed (Thousand Barrels Per Day)

	PADD 1	PADD 2	PADD 3	PADD 5	Total U.S.
Loss of MTBE Volumes	-113	0	-93	-101	-306
Addition of Ethanol to RFG(2)	75	0	18	58	151
Reduction in Light Ends for RVP	-21	0	-37	-50	-108
Reduction of Heavy Ends for Distillation Points	-12	0	-9	-16	-37
Refinery Increased Alkylate Production	9	10	71	17	107
Commercial Alkylate or Iso-Octane Production	0	0	25	10	35
Added Ethanol in Conventional	0	-20	0	0	-20
Total	-62	-10	-25	-82	-179

(1) These estimates do not take into consideration additional volume losses due to MSAT constraints on refiners switching from MTBE to ethanol.
(2) No volume adjustment for energy content differences is needed in this table since ethanol has a lower Btu content (76,000 Btu's) than MTBE (93,500 Btu's), and 5.8 percent ethanol is being assumed to substitute for 11.2 percent MTBE as illustrated for a gallon of 115 thousand Btu finished gasoline:
$115 = 0.112*93.5 + .888*117.7$ and
$115 = 0.58*76 + 0.942*117.7$
Totals may not equal the sum of the components due to independent rounding
Source: Energy Information Administration

Table 18 shows PADD 1 RFG-quality imports separated into finished RFG, RFG blending components, and RBOB for ethanol blending. In 2000, PADD 1 imported 370 thousand barrels per day of RFG quality materials. In the High Capacity Scenario, that volume grows to 410 thousand barrels per day in 2007 with no MTBE ban. It grows an additional 56 thousand barrels per day to reach 466 thousand barrels per day with the ban, but the imports now are RBOB for ethanol blending.

Table 17. PADD 1 Comparison Of Scenario Impacts of MTBE Ban (Thousand Barrels Per Day)

		Gasoline Demand	Refinery Capacity	Gasoline Production		Net Receipts	Net Finished Imports	Blending Component Imports
				Refinery	Blenders			
History	2000	2,988	1,704	836	186	1,578	397	199
High Capacity								
No Ban	2007	3,407	1,869	925	187	1,820	474	200
MTBE Ban	2007	3,407	1,869	875	519	1,798	214	498
Low Capacity								
No Ban	2007	3,407	1,570	776	348	1,588	695	350
MTBE Ban	2007	3,407	1,570	737	661	1,589	420	635

MB/D = thousand barrels per day
During 2000, stock draws contributed about 10 thousand barrels per day to demand.
Blender component contribution to production and imports was separated due to the historically large imports of blending components, much of which has been RFG quality fuel.
Net Receipts are flows of product from other regions
Totals may not equal the sum of the components due to independent rounding
Source: Energy Information Administration

Table 18. Estimated PADD 1 Imports of RFG-Quality Volumes

		RFG	Blending Components for RFG	RBOB for Ethanol	Total RFG-Quality Imports
		MB/D	MB/D	MB/D	
History	2000	194	176		**370**
High Capacity					
No Ban	2007	234	176		**410**
MTBE Ban	2007	0	0	466	**466**
Low Capacity					
No Ban	2007	262	300		**562**
MTBE Ban	2007			610	**610**

Source: Energy Information Administration

The Low Capacity Scenario reaches 562 thousand barrels per day of RFG quality imports in the No-Ban Case in 2007, which is an increase of 192 thousand barrels per day over

2000. With an MTBE Ban, the region's RFG quality imports grow by 240 thousand barrels per day over 2000 to reach 610 thousand barrels per day.

PADD 5 supply-demand balances are shown in Table 19. In PADD 5, the High Capacity Scenario indicates 117 thousand barrels per day of extra supply from other regions (mainly PADD 3) is needed in 2007 to meet demand. This is an increase of 33 thousand barrels per day of RFG-quality gasoline over levels required in 2000. Under an MTBE ban, this flow must rise to 184 thousand barrels per day. In the Low Capacity Scenario, capacity increases very little between 2000 and 2007, which results in the region requiring 283 thousand barrels per day of California reformulated gasoline from the Gulf Coast in 2007, or an increase of 200 thousand barrels per day, to meet demand. The MTBE-Ban Case assumes the Gulf Coast responds to fill the loss of volumes that occurs from the No-Ban Case. Flows into the State in this situation would have to increase another 55 thousand barrels per day over the No-Ban case to cover the loss of refining capability. Because these volumes have not been available historically, changes to refinery configurations on the Gulf Coast will need to be implemented.

Table 19. PADD 5 Comparison Of Scenario Impacts of MTBE Ban (Thousand Barrels per Day)

	Year	Gasoline Demand	Refinery Capacity	Refinery Gasoline Production	Net Receipts	Net Finished Imports
History	**2000**	**1,479**	**3,095**	**1,387**	**84**	**8**
High Capacity						
No Ban	2007	1,666	3,493	1,528	117	20
MTBE Ban	2007	1,666	3,493	1,461	184	20
Low Capacity						
No Ban	2007	1,666	3,116	1,363	283	20
MTBE Ban	2007	1,666	3,116	1,307	339	20

MB/D = thousand barrels per day
All production is assumed to be blended by refiners.
Net Receipts are flows of product from other regions
Totals may not equal the sum of the components due to independent rounding
Source: Energy Information Administration

In summary, under both the High Capacity Scenario and the Low Capacity Scenario, the loss of gasoline production volumes is very similar, about 150-166 thousand barrels per day for RFG and 20 thousand barrels per day for conventional gasoline. The two scenarios present different import dependencies and show different needs for PADD 3. With less capacity, higher product imports are required to meet growing demand, including higher RFG-quality gasoline imports. An MTBE Ban requires an increase in RFG-quality imports in the form of RBOB. RBOB may be less available than RFG has been historically because of its very low RVP requirements, which are unique to the United States. In addition, PADD 3 will likely be providing more California gasoline quality material to PADD 5 than historically. Thus, further refinery investments may be needed in this region.

Transitions in 2004 and 2007

This analysis focused on the volume differences between a No-Ban world and a 100-percent ban world in the year 2007. The roughly 180 thousand barrel per day gap is the cumulative gap that would develop beginning with the 17 States banning MTBE in 2004. This first transition represents about 45 percent of all MTBE-blended RFG, but California represents most of the volumes. Thus, the 2004 transition is mainly a West Coast transition that will resolve the uncertainties of how this region will find its additional supplies.

New York and Connecticut on the East Coast are also scheduled for a 2004 MTBE ban. They represent about 26 percent of East Coast RFG. Refineries on the East Coast that now supply gasoline to those two regions will experience the yield losses mentioned above and will have to deal with MSAT issues. But since at least 80 percent of East Coast RFG will still be using MTBE, the uncertainty surrounding RBOB availability from import sources should not be as large a transition issue as when a total ban is implemented in 2007.

Transition problems do not imply MTBE-free gasoline cannot be achieved. They only indicate the potential for price volatility and market dislocations while getting to the goal. The MTBE ban requires a complex transition with many different players, both domestically and internationally. The solution involves investments and production of materials that are not now being produced (e.g., extra alkylate) and for which final volume requirements are unknown. It also involves much regulatory uncertainty.

There is no good analogy historically, but the transition to the RFG program in 1995 provides some insights. That program required changes in both domestic players and international import refineries. As the program began, imports of reformulated gasoline were sluggish. However, consumers were spared major difficulties as a result of regulatory uncertainties. A number of regions opted out of the program at the last minute, leaving refiners with too much RFG capacity for demand in spite of the loss of imports. Refiners learned the cost of regulatory uncertainty during that transition.

Considering the issue from an individual company's perspective, there is considerable uncertainty about whether a State will postpone its ban at the last minute, or will opt out of the Federal program in 2007. A refiner will have a strong disincentive to make any "speculative investment," such as providing volumes for more than minimum contract requirements. With a large number of players, an individual company will also find it more difficult to estimate what supply will be available. If the market comes up short, the refiner will make good margins on the volumes that can be produced, and will know where new volumes are needed. If the market is oversupplied, the refiner will have trouble making a good return on the minimum investments that were made. Finally, if the refiner has prepared and the ban is postponed, that facility will have to carry its preparatory investments unprofitably until the ban is instituted. There is more downside financial risk to doing more than the minimum than to doing the minimum and waiting to see how the market and regulatory uncertainties are resolved.

Both market and regulatory uncertainties will be present during each transition. The complexity of the changes both in number of players involved and magnitude and types of changes required to meet the bans have the potential for a challenging transition.

Uncertainties

The following uncertainties affect the analysis results.

California

This study assumes California will be able to supplement its own refinery production of California RFG with a combination of alkylate imports and supply from the Gulf Coast. Yet, the availability of alkylate or other components meeting California gasoline quality specifications is still unknown. Since some refineries have begun producing California RFG with ethanol, technical issues are being resolved. However, the California Energy Commission (CEC) is estimating a potential shortfall of 3-5 percent in California reformulated gasoline in 2004, when that State is scheduled to eliminate MTBE.[16] The transition to MTBE-free gasoline, scheduled for the end of 2003, could be a challenge if CEC's analysis proves to be correct.

Mobile Source Air Toxics Rule (MSAT)

Potential MSAT impacts are not quantified in this analysis. Such an analysis would require individual refinery information not readily available to EIA and analysis that time constraints prevented for this paper. However, it will be critically important to deal with the potential MSAT implications in considering MTBE ban supply impacts.

The combination of eliminating MTBE and complying with the MSAT "anti-backsliding" toxics requirement would likely create a large hurdle for some East Coast refiners, resulting in significant RFG production losses in several refineries now providing large volumes of RFG to the Northeast. In addition to the volume losses, the region may experience unintended air quality deterioration. With no adjustment to MSAT, refineries with cleaner baselines which are now producing large volume fractions of their product as RFG could experience a significant loss in RFG production capability due to MSAT's anti-backsliding constraint. These refineries represent an important fraction of current Northeast RFG supply. The refineries that could most easily produce volumes would be those with lower fractions of RFG and higher toxic emissions during the baseline period. This could result in an increase in average toxics for the pool of RFG

[16] Conference call between EIA and CEC, July 29, 2002.

available to the Northeast. The MSAT constraints with an MTBE ban could even lead to further refinery shutdowns as the competitive landscape shifts away from the historically clean producers. In summary, because the supply-demand balance between now and 2007 is expected to remain tight, if MTBE is banned on the East Coast without any regulatory changes or adjustments to MSAT, there is the potential for RFG shortfalls in the Northeast during the transition.

Demand and Capacity Uncertainties

The balance between supply and demand and the resulting need for imports is uncertain. Demand growth will change with economic changes, as will capacity. For example, the High Capacity Scenario has capacity growth keeping pace with demand growth as it did from 1995 through 1999. The situation could change. Refinery margins have been depressed this past year, and poor margins can diminish the rate of expansions as well as accelerate refinery closures. Furthermore, the high capital investment requirements of the upcoming regulatory changes such as low sulfur gasoline and ultra-low sulfur diesel programs could accelerate shutdowns of less efficient refineries. If lower capacity growth occurs, it results in higher imports, which also are not assured.

Import Uncertainties

Import uncertainties will mainly affect PADD 1, since most gasoline imports go into this region. Import suppliers do not all have the same dependence in the U.S. market. Some are dedicated suppliers highly reliant on the U.S. market, and others are opportunistic suppliers, providing volumes to the most profitable market at the time, when they have excess volumes to provide. The most dedicated sources of supply come from Canada, the U.S. Virgin Islands, and Venezuela. When the United States moved into the RFG program, finished gasoline and blending component imports from the Virgin Islands and Venezuela held steady, and Canadian imports increased. However, finished gasoline and blending component imports from Western Europe, a major import source, fell by 42 percent from 128 thousand barrels per day to 74 thousand barrels per day. Western Europe import volumes came back up in 1996 to 163 thousand barrels per day, an even higher level than in 1994.

Western Europe is likely to provide diminishing RFG components over the next 5 years, even without an MTBE ban. This region is also requiring cleaner gasolines. Refiners are facing regulatory uncertainties and market uncertainties and are planning on re-directing the clean streams they had been using for U.S. RFG for their own needs. They also are not planning on much increase in export availability during this time period. More conventional gasoline will be available for export, but less RFG. The MTBE Ban could exacerbate this shrinking volume. Europe uses MTBE and does not have to create the low-RVP RBOB U.S. markets will require after a ban. The opportunistic refiners will have little incentive to invest for RBOB production in advance of any transition. They will most likely wait to see if prices are adequately attractive to warrant such investment.

Conclusion

This analysis quantified part of the potential supply impacts of removing MTBE from the system. It illustrated on an individual refinery basis that a net loss in gasoline production capability derives from:

- Replacing MTBE with about half as much ethanol,
- Losing high-RVP, light components to balance ethanol's high RVP, and
- Losing heavy components to balance distillation temperatures.

By the time a full ban has been implemented, assuming many refinery MTBE facilities convert to producing more alkylate to help make up for lost volumes, refiners are expected to lose production capacity of about 159-166 thousand barrels per day of RFG and 20 thousand barrels per day of conventional gasoline in 2007. This will not occur all at once, but in several major steps, beginning with the 2004 State bans now in place. While the ultimate goal of producing MTBE-free gasoline is achievable, the transition to achieving that goal will be challenging.

The volumes lost are RFG volumes, which are the most difficult to replace; however, refiners have several options to help regain these losses. The first is simply to increase crude and unfinished oils inputs, thereby producing more gasoline as well as other products. This requires adequate distillation capacity and other gasoline processing downstream of the distillation unit to increase throughputs.

The second is to find other clean components that will not distort the emissions and driveability characteristics of the gasoline. Alkylate and iso-octane are two such components. Additional alkylate can be produced from the feedstocks being used to produce MTBE. Refineries and petrochemical plants that have MTBE production facilities and that are generating the feedstock themselves are likely to re-direct the feedstocks to alkylation units, which may have to be expanded or built to accommodate the extra volume. However, economics are not currently favorable for "on purpose" or commercial MTBE production facilities that do not have a captive feedstock source to invest for converting facilities to iso-octane or alkylation production.

The third option is to add more ethanol. In some cases, refiners can add more than the 5.8 volume percent ethanol to RFG to meet the Federal 2 weight percent oxygen requirement. Ethanol's tendency to increase evaporation from gasoline peaks at about 5.8 percent. Thus, increasing to 10 volume percent does not produce any further VOC penalty. Refiners producing California reformulated gasoline, however, run up against a NO_x emission limit and will find it difficult to add much more ethanol. These additional ethanol volumes for RFG might have to come from ethanol plants built on speculation that refiners will not only opt to use 10 percent ethanol in the short-term, but in the long-term as well.

Last, refiners may find more RFG volumes from import refineries, but this volume is not assured. A major opportunistic supply region to the United States, Europe, is expected to consume more of the clean gasoline it now sends to the United States in the future, as its own gasoline requirements change. California RFG is unique in the world and is more difficult to produce than Federal RFG, so import options and other U.S. refinery suppliers are limited. After an MTBE ban, base gasoline to which ethanol is to be added, referred to as Reformulated gasoline Blendstock for Oxygenate Blending (RBOB), requires a very low RVP to accommodate ethanol's RVP increase. No other place in the world requires such low-RVP gasoline components, implying some import suppliers may choose to wait and see if prices merit the investment. Losses of conventional gasoline could be replaced more easily by foreign suppliers than losses of RFG.

In this study, the refinery yield loss assumption was combined with a regional supply-demand balance calculation for the United States in which, with an MTBE ban, the utilization was increased and estimates of refinery and commercial ether plant conversions to alkylate were included. This resulted in a need for RBOB imports to increase over 50 thousand barrels per day from the case in which MTBE was used.

Much has to change to switch from MTBE-blended RFG to MTBE-free RFG. The result of this analysis indicates that the following factors would improve the chances of relatively smooth transitions to MTBE Bans:

- Capacity growth rates would need to keep pace with demand to minimize dependence on product imports and to allow for some increase in utilization to contribute to volume losses resulting from a ban;
- PADD 3 refiners would need to adjust configurations to be able to supply more California-quality gasoline to PADD 5;
- The MSAT issue would need to be resolved prior to East Coast transitions to prevent additional RFG production losses for refiners providing RFG to PADD 1;
- Some refiners and ethanol producers would need to invest before the transition in facilities to produce extra alkylate (107 thousand barrels per day) and extra ethanol to improve the economic attractiveness for blending ethanol at 10 percent rather than 5.8 percent where possible. However, regulatory and market uncertainties may produce strong disincentives to invest in these areas prior to the transition; and
- RBOB import volumes would need to be at least as great as historical RFG and RFG blending component imports.

Supply problems have occurred during fuel specification transitions historically. Given the uncertainties associated with the transition to an MTBE ban, there is a significant probability of localized and/or regional supply problems occurring during such a transition. There is no way to determine the magnitude or duration of a supply problem until much closer in time to the transition deadline. Market and even regulatory uncertainties will provide strong disincentives for both the domestic industry and many foreign import refiners to make many speculative investments in advance of the transition. As the market sorts itself out, it will be clearer where more investment is needed and the time that it might take to resolve potential problems.

Appendix A. Request from Committee and EIA Interim Response

Request from Committee

JEFF BINGAMAN, New Mexico, Chairman

DANIEL K. AKAKA, Hawaii
BYRON L. DORGAN, North Dakota
BOB GRAHAM, Florida
RON WYDEN, Oregon
TIM JOHNSON, South Dakota
MARY L. LANDRIEU, Louisiana
EVAN BAYH, Indiana
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June 17, 2002

Dr. Mary Hutzler
Acting Administrator
Energy Information Administration
1000 Independence Avenue SW
Washington, DC 20585

Dear Acting Administrator Hutzler:

The Senate passed version of H.R.4 contains a number of provisions affecting fuels markets that require additional analysis prior to final conference decisions. First, the oxygenate requirement for RFG would be eliminated and the states would be allowed to ban the use of MTBE beginning in 2004, a national phase out would follow. Also beginning in 2004, a certain portion of all gasoline sold in the U.S. will have to be from "renewable fuels", this requirement will affect all refiners and gasoline markets. The combination of these two factors alone has the potential to significantly impact US motor fuels markets.

As we all know too well, every previous significant change to fuel formulations has resulted in severe price volatility in various US motor fuels markets. Each time, the Committee on Energy & Natural Resources has held hearings to review the problems in an effort to avoid or at least mitigate future recurrence of such dislocations. The Energy Information Administration (EIA) has also investigated and reported on these various transitions. We should be able to apply what we have learned from these past market transition experiences to ease the implementation of these various changes that will start to take effect in 2004.

Therefore, I am requesting that the EIA analyze the potential market implications of the Senate-passed fuels provisions in H.R.4 combined with known and anticipated regulatory changes. This should include specific analysis of the following factors:

1. The expected volumetric shortfall in fuels supplies with an effective MTBE ban in 2004;
2. Actual renewable fuels production capacity, supply, and constraints and the effect on price;
3. Inter-regional transportation issues and associated costs for renewable fuels;

4. The potential effect of operating the mandate on a fiscal year, (i.e. beginning in October) vs. calendar year basis;
5. The environmental impact of the simultaneous implementation of the low sulfur and Mobile Source Air Toxic (MSAT) gasoline regulations and a national ethanol mandate;
6. The impact on gasoline price and supply when many additional ozone non-attainment areas come under the new 8-hour ozone standard;
7. The potential cost and supply impacts associated with individual states seeking to protect air quality through the removal of the one-pound vapor pressure waiver for gasoline blended with ethanol;
8. The potential effect/role of implementation of a national menu of fuels to address the proliferation of boutique fuels.

As earlier requests have noted, it would be helpful to have this study completed as soon as possible. Should you have any questions, regarding this request, please contact Jennifer Michael at the Committee, at (202)224-7143. I thank you in advance for your assistance.

Sincerely,

Jeff Bingaman
Chairman, Senate Committee on
Energy & Natural Resources

cc: file

EIA Interim Response

June 21, 2002

The Honorable Jeff Bingaman
Chairman
Committee on Energy and Natural Resources
United States Senate
Washington, DC 20510-6150

Dear Mr. Chairman:

This responds to your request of June 17, 2002, for information on potential impacts that the Senate-passed version of H.R. 4 might have on petroleum markets. Because we cannot provide quantitative answers to all of your questions within the time limits that would be useful for your deliberations, we will provide some qualitative responses. In the next 6 to 8 weeks, we plan to address your questions as follows:

1) **Expected volume shortfall in fuel supplies with an effective methyl tertiary butyl ether (MTBE) ban in 2004**: We will use a simple volume-balancing approach to quantify the volume loss of MTBE, the various means of making up that reduction, the potential volumes associated with those means, and the hurdles to exercising those supply responses.

2) **Actual renewable fuels production capacity, supply, and constraints and the effect on price**: We will look at current capacity, planned additions, and capacity needed beyond that already announced to provide required ethanol supply between now and 2007. Consideration will be given to needed ethanol supply both with and without an MTBE ban, since our prior analysis of MTBE bans showed an increase in demand for ethanol above the Renewable Fuel Standard (RFS) in earlier years. We will also discuss potential impediments and price impacts.

3) **Inter-regional transportation issues and associated costs for renewable fuels**: Because the Energy Information Administration has not done an independent study on this issue and because of your time constraints, we will respond to this request by summarizing recent studies on the transportation issues associated with distribution and storage of ethanol.

4) **The potential effect of operating the mandate on a fiscal year (i.e., beginning in October) vs. calendar year basis**: It is our understanding from your staff that this question is intended to address the startup of an RFS program and whether delaying the start date from January to October 2004 (thereby starting the program after the high-demand summer season) would reduce the potential for price volatility. We will provide a qualitative answer to this issue after investigating the operating issues in more detail.

5) **The environmental impact of the simultaneous implementation of the low sulfur and Mobile Source Air Toxic (MSAT) gasoline regulations and a national ethanol mandate:** We understand that this question is meant to explore whether spreading the start dates further apart for the low sulfur programs and ethanol mandate could reduce the potential for supply dislocations and associated price volatility. Because MSAT is currently in place, we will explore adjusting the start dates for low sulfur gasoline, low sulfur diesel, and the ethanol mandate. As in question 4, we will provide a qualitative answer to this issue after investigating the operating issues in more detail.

6) **The impact on gasoline price and supply when many additional ozone non-attainment areas come under the new 8-hour ozone standard**: Once we have obtained guidance on the assumptions for the desired reformulated gasoline (RFG) requirement scenarios from your staff, we will analyze the implications of adding the new RFG regions.

7) **The potential cost and supply impacts associated with individual states seeking to protect air quality through the removal of the one-pound vapor pressure waiver for gasoline blended with ethanol:** The impact of the waiver is on summer gasoline. Because we do not have the modeling ability to analyze seasonal variations in gasoline specifications, we will estimate the potential volume of supply that would be backed out of the summer gasoline pool to meet the lower Reid Vapor Pressure (RVP) standard and assess the refiners' abilities to make up that supply. We will also qualitatively discuss other aspects of the issue that may affect supply.

8) **The potential effect/role of implementation of a national menu of fuels to address the proliferation of boutique fuels**: The boutique fuel issue is complex, and no one to our knowledge currently has the capability to quantitatively analyze the price impacts of reducing the number of fuels. However, we can assist the Committee in understanding what dimensions need to be considered when proposals are raised to reduce the number of fuels. We will do this by defining the source of the boutique fuel problem and describing the major market dimensions of these fuels that increase the potential for price volatility.

We will provide you with answers to as many of these questions as possible by the end of July with the remainder completed in August. Please call me on 202/586-4361 should you need further information regarding this request.

Sincerely,

Mary J. Hutzler
Acting Administrator
Energy Information Administration

cc: The Honorable Frank Murkowski
Ranking Minority Member

Appendix B. MTBE Ban Effects on California

California refineries are affected differently by an MTBE ban than other refineries because they produce a different type of gasoline, CARB reformulated gasoline, and, as a result, they have different equipment than most other refineries. The subject of an MTBE ban has been a topic of discussion and analysis in California for a number of years and the volume and quality of analysis done on a California MTBE ban exceeds that done for other U.S. regions. Moreover, recent surveys by the California Energy Commission (CEC) of refiners' production plans when MTBE is eliminated provide a check on past analyses. This appendix summarizes how individual California refineries are affected by an MTBE ban, and estimates the aggregate impact on the California supply-demand balance.

California Refineries

California refineries producing CARB reformulated gasoline have to meet more stringent gasoline requirements than refineries producing Federal RFG, and they are configured differently to produce this unique fuel. Furthermore, these refineries are not subject to the Mobile Source Air Toxics Rule, as indicated in the rule.

A study on the impact of an MTBE ban in California was done by Purvin & Gertz and Stratco (alkylation process experts).[17] The results of this study are summarized in the following excerpts from the report:

> West Coast Refinery
>
> The West Coast refinery case evaluations are based on a coking facility that processes 200,000 barrels per day of Alaskan North Slope crude and produces 100 percent CARB Phase II gasoline (CaRFG II), jet fuel, 30 percent CARB-compliant diesel and 70 percent low-sulfur diesel. While most West Coast refineries do produce some conventional gasoline, the objective of the current study is to demonstrate the impact of producing compliant gasoline within the constraints of an MTBE ban and [CARB] Phase III specifications.
>
> The study revealed that assuming a MTBE ban and constant crude throughput, gasoline production would decrease for the refiners studied. Additionally, blending ethanol will increase the required amount of pentane removal from the gasoline pool in order to meet RVP specifications. Determining an economical disposition for the excess pentanes will be an additional challenge for refiners. While there is no simple processing alternative that can eliminate the shortfall in gasoline production caused by an MTBE ban, several options can be used to minimize the loss.
>
> The options studied are outlined below. Each option involved shutdown of the MTBE unit and increases in the amount of alkylate available for gasoline blending.
>
> - [Case II] Send the incremental i-C_4 (previously MTBE unit feed) to the alkylation unit

[17] Melissa Graham, Pam Pryor, Michael Sarna "Refining Options for MTBE-Free Gasoline," Stratco Inc. and Purvin & Gertz, Inc., NPRA AM-00-53, paper presented at the annual NPRA meeting in 2000. http://www.stratco.com/pdf/RefiningOptionsPaper.pdf

- [Case III] Add…catalyst to produce more olefins for alkylation
- [Case IV} Separate FCC C_5 olefins for additional alkylate production

Table B-1 taken from the Stratco/Purvin & Gertz study summarizes their California refinery analyses.

Table B-1.
West Coast Refinery Results

Case	Gasoline Production Pool Volume BPD	Gasoline Production Change percent	Pentane Sales BPD	Ethanol (MTBE) BPD	Isobutane Purchased BPD	Incremental Alkylate Production BPD	Process Capacity Changes*
Base	123,172		0	(13,243)	0	Base	
II	103,516	-16.0	8,321	6,286	1,737	+2,466	1,2,4,6,7
III	101,833	-17.3	9,310	6,184	2,872	+4,386	1,2,3,6,7
IV	114,321	-7.2	1,471	7,815	5,473	+11,528	1,4,5,6,7

BPD = barrels per day

*Process Capacity Notes:

1. New light straight run (LSR) Depentanizer
2. Expand Isomerization
3. Expand Distillate Hydrocracking
4. Expand FCC Gasoline Hydrotreating
5. New FCC Gasoline Depentanizer
6. Olegin Treating (mercaptan removal and selective hydrogenation)
7. Expand Alkylation

Source: "Refining Options for MTBE-Free Gasoline" NPRA AM00-53, presented at NPRA's Annual Meeting in 2000. http://www.stratco.com/pdf/RefiningOptionsPaper.pdf

In summary, this study shows gasoline production losses of 7-17 percent when MTBE is replaced with ethanol.

EIA has done an analysis using a 100-thousand-barrel-per-day refinery with a process configuration similar to that used in the Stratco/Purvin & Gertz study. The main difference between the EIA and the Stratco/Purvin & Gertz study is that EIA used a higher percent of normal butane (n-butane). Since n-butane has a very high RVP, EIA's estimated volume loss due to reduction of light, low-boiling-point material is less.

The EIA cases that analyzed gasoline production to meet CARB summer specifications are summarized in Table B-2. The cases were designed to analyze several issues and options facing California refiners. The first issue focused on the volume of ethanol California refiners might use to meet customers' needs. The RVP impact of ethanol on the gasoline blend is nonlinear, with the greatest impact occurring with only a few percent of ethanol. By the time 5.8 volume percent is reached, the adverse RVP impact has been fully absorbed. That is, the RVP impact on a 5.8-percent blend is about the same as the impact on a 10-percent blend. So, why wouldn't CARB reformulated gasoline producers add 10 percent to help make up for the volume loss when MTBE is eliminated? The answer is that it can't be done in most cases and still meet emission constraints. The issue arose with the particular refinery gasoline pool used in EIA's analysis. In developing EIA's Case 2, ethanol is at 5.8 volume percent and could only be increased to 6.0 percent before this particular blend failed the CARB predictive model NO_x emission test. Case 4 demonstrates that it is possible to get to 7.0 percent ethanol if the refiner can also purchase additional volumes of alkylate and iso-octane, but 10 percent was not practically achievable.

The EIA results found that the volume of total gasoline production from this refinery could easily be restored to the MTBE volume levels with purchased alkylate (Case 5). Purchased alkylate was increased enough to match the prior MTBE-blended gasoline volumes and no emissions constraints occurred. Furthermore, Cases 3 and 5 show that, with increased C_4 alkylate in the gasoline pool, more heavy ends could be added back into the mixture. The troublesome issue with the alkylate solution is whether adequate volumes of alkylate will be available for purchase from other U.S. refinery regions or internationally at a reasonable price during the startup of the MTBE bans.

California Aggregate Supply Impacts of an MTBE Ban in 2004

Using the information learned from the individual refinery analyses, estimates about refinery adjustments, volumes losses and means of making up those losses on an aggregate basis can be made. This section explores total losses to California production capability and compares EIA results to those of a recent analysis commissioned by the CEC.

California produces about 40 percent of the reformulated gasoline produced in the U.S. and consumes about 40 percent of the MTBE. As such, a California MTBE ban has ramifications that extend beyond that region. Not only will significant volumes of ethanol be needed, significant volumes of gasoline components such as alkylate will have to come from the Gulf Coast or import sources, which is described below.

The California Energy Commission has developed California supply-demand balances and described some of their analyses in a presentation in July 2001.[18] In that presentation, a Commission representative stated, "ethanol provides little supply benefit during the majority of the year." The presentation discussed how volume losses occur both due to less ethanol being used than MTBE and due to removal of pentanes to balance ethanol's high RVP during the low-RVP season (8 months per year in California). The gap would need to be filled by importing key blendstocks, primarily alkylate. In discussing the role of alkylate for both volume and specification purposes, another California Energy Commission presentation indicated the alkylate volume needs from outside the California refineries might top 50 thousand barrels per day.[19]

[18] Schremp, Gordon, "MTBE Phaseout Update – Costs, Supply, Logistics, & Key Challenges," California Air Resources Board Hearing, San Francisco, CA, July 26, 2001.
[19] Schremp, Gordon, "California Issues – Expanded Use of Ethanol and Alkylates," LLNL Workshop, Oakland, CA, April 10-11, 2001.

Table B2. MTBE Ban Impacts on CARB Gasoline Production 100MB/D Illustrative California Refinery

Case:	Base Case		Case 2		Case 3		Case 4		Case 5	
	CARB with MTBE		5.7% Ethanol, Reduce C_5's,		Increase Alkylate Purchase over Case 2		Restore Full Production		Restore Full Production	
			C_3 Alkylate Production + Purchae		Restore Some Light & Heavy Components		Increase Alkylate, Iso-Octane & Ethanol		5.7% Etanol & Alkylate	
	Volume (MB/D)	Vol %	Volume (MB/D)	Vol %	Volume (MB/D)	Vol %	Volume (MB/D)	Vol %	Volume (MB/D)	Vol %
Production										
LSR	7.5	13.0	4.7	9.2	5.0	9.2	5.5	9.5	5.3	9.1
Isomerate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Reformate	16.9	29.1	15.5	30.4	16.0	29.5	16.7	28.8	16.6	28.8
FCC Gasoline	16.5	28.5	15.7	30.8	15.7	28.9	15.7	27.1	15.7	27.1
Alkylate	9.5	16.4	11.5	22.5	11.5	21.2	11.5	19.8	11.5	19.8
n-Butane	1.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refinery	51.4		47.4		48.2		49.4		49.1	
Purchases										
MTBE	6.5	11.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ethanol	0.0	0.0	2.9	5.7	3.1	5.7	4.1	7.0	3.3	5.7
C_4 Alkylate	0.0	0.0	0.7	1.4	3.0	5.5	2.0	3.5	5.5	9.5
C_3/C_4 Alkylate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Iso-Octane	0.0	0.0	0.0	0.0	0.0	0.0	2.5	4.3	0.0	0.0
Total Purchases	6.5		3.6		6.1		8.6		8.8	
Total Gasoline	57.9		51.0		54.3		57.9		57.9	
Properties										
Octane: (R+M)/2	88.6		88.3		88.5		89.1		88.8	
RVP: psi	6.5		7.0		7.0		7.0		6.98	
Benzene: vol %	0.32		0.36		0.34		0.32		0.32	
Aromatics: vol %	25.0		25.7		24.8		24.0		23.9	
Olefins: vol %	7.6		8.5		8.0		7.5		7.5	
Sulfur: ppm	12		12		11		11		11	
ASTM D86 T50	196		208		209		209		209	
ASTM D86 T90	335		326		326		329		327	
CARB	PASSES		PASSES		PASSES		PASSES		PASSES	
Predicted Percent Change In Emissions (Candidate vs Reference)										
NO_x	-1.14		-0.29		-0.79		-0.36		-1.29	
Exhaust THC	-0.19		-0.12		0.01		0.01		-0.14	
POT.TOX.	-9.24		-6.69		-8.22		-9.49		-9.67	

Definition of abbreviations and technical terms:

LSR = light straight run;
FCC = fluid catalytic cracking;
ppm = parts per million;
psi = pounds per square inch;
vol% = volume percent;
MB/D = thousand barrels per day;
MTBE = methyl tertiary butyl ether;
RVP = Reid vapor pressure;
THC = total hydrocarbons;
POT. TOX. = potency weighted toxins.

Source: Energy Information Administration

In 2001, CEC also commissioned Stillwater Associates[20] to analyze the California supply situation under an MTBE ban. Stillwater results are shown in Table B-3. When 102 thousand barrels per day of MTBE is removed and replaced with 55 thousand barrels per day of ethanol, the volume of light, high RVP products (C_4's and C_5's) removed is 46 thousand barrels per day. In addition, 10 thousand barrels per day of heavy, low RVP components must be removed. Given the same level of crude oil throughputs (which is a reasonable assumption for California), the net result is a loss of volume of 103 thousand barrels per day, or a loss of 10 percent over what had been produced when MTBE was used.

CEC has not only commissioned studies on the subject, but has been monitoring refiner's plans and actions to eliminate MTBE and find additional supply. CEC's recent assessment of the supply situation with an MTBE ban was that the Stillwater results are a very good reflection of the yield impacts that refiners are experiencing. CEC's current estimate is that, after refiners' process adjustments, expansions, planned blendstock imports and shift from conventional to CARB production, there still remains a potential CARB supply shortfall of 3-5 percent.[21]

In order for EIA to compare its refinery yield impacts to the Stillwater study volumes, EIA annualized its results, using the Stillwater production estimates. The comparison is shown in Table B-4. The EIA estimates are slightly higher because, with the components available in the blending model, less light-ends adjustment had to be made, but a larger heavy-ends' adjustment more than offset the light-ends' adjustment, resulting in a slightly higher total. For EIA's regional supply-demand balance, the Stillwater estimates are used because Stillwater, through the auspices of the CEC, had better information on actual refinery plans.

Using the loss of production capability on existing refinery capability as described in this section, results were extended to 2007 under both the High and Low Capacity Scenarios to analyze the U.S. supply-demand balances covered in the body of the report.

[20] Finizza, Anthony J. et al, *MTBE Phase Out in California, Draft,* Stillwater Associates for the California Energy Commission, March 14, 2002.
[21] Conference call between EIA and CEC, July 29, 2002.

Table B-3. Stillwater Associates Study for California Energy Commission on Impact of MTBE Ban (Thousand Barrels per Day)		
CARB Reformulated Gasoline Production Using MTBE		
	RFG Production	935
	Ethanol Based CARB RFG	110
	MTBE Based CARB RFG	825
	MTBE Required @ 11%	91
MTBE Supply		
	MTBE Foreign Imports	75
	MTBE Gulf Coast Net Receipts	17
	MTBE Production	10
	Total MTBE Supply	102
	Excess MTBE	11
Direct Impact with MTBE Ban		
	Removal of MTBE	-102
	Ethanol Addition for Oxygen Requirements	55
	Removal of Butanes and Pentanes	-46
	Other Losses to meet distillation specs	-10
	Net Loss *	-103

* Net loss is the volume to be filled by refinery modifications to increase gasoline production and imports of blending components and finished CARB reformulated gasoline.
Source: Finizza, Anthony J. et al, MTBE Phase Out in California, Draft, Stillwater Associates for the California Energy Commission, March 14, 2002

Table B-4. Net Change in Volume If Ethanol Were Used in CARB RFG in 2002 (Thousand Barrels per Day)

	Stillwater Analysis	**EIA**
MTBE Removal	-102	-102
Ethanol Addition	+55	+55
Loss of Light & Heavy Components to Balance Ethanol Properties	-56	-68
Net Impact on Volume	-103	-114

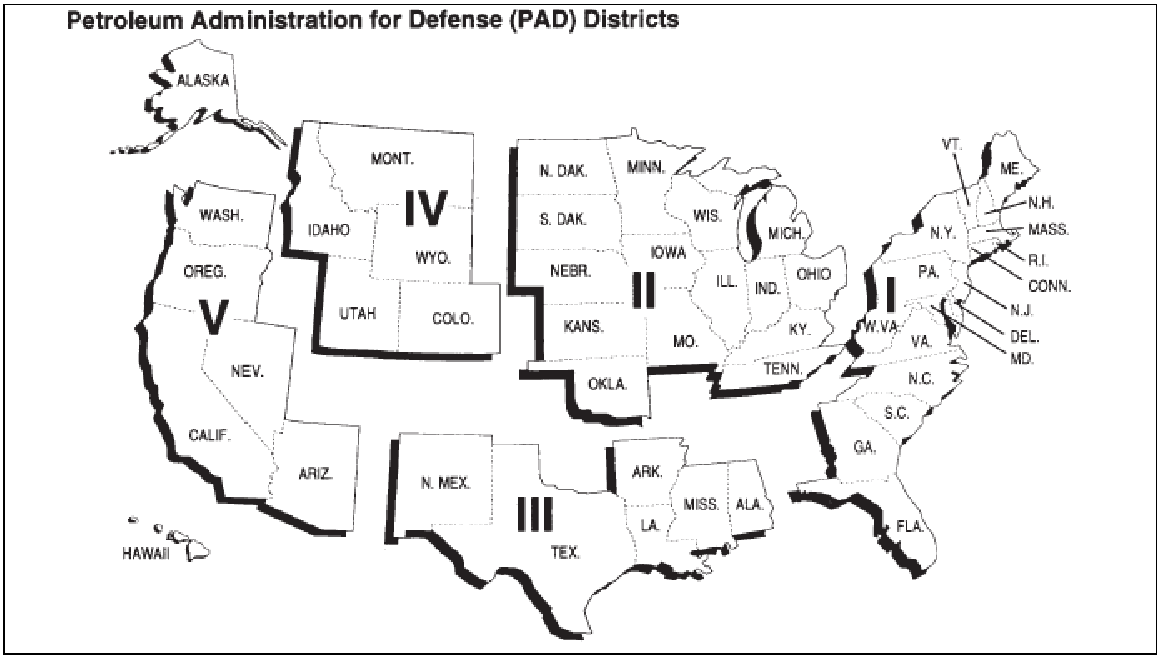
Note: The Stillwater analysis estimated yield impacts for the MTBE to ethanol shift in California reformulated gasoline. This table showed the effect of those yield reductions using end of 2002 demand and refinery production. The study then indicated that the impacts likely would increase by 2004, when the ban is currently scheduled to begin. The EIA result column applied EIA's refinery yield reductions to the same volumes.
Sources: Finizza, Anthony J. et al, MTBE Phase Out in California, Draft, Stillwater Associates for the California Energy Commission, March 14, 2002; Energy Information Administration.

Appendix C. New Sources of Alkylate and Iso-Octane

Alkylate and iso-octane have frequently been discussed as attractive gasoline blend components to deal with supply issues if MTBE is eliminated. Like MTBE, these materials are free of benzene, other aromatics, olefins, and sulfur. The largest difference is octane. MTBE has an octane rating (R+M/2) of about 110, while alkylate is 92-94 and iso-octane is about 98. If MTBE is banned, most analysts assume that the iso-butylene feed streams to refinery MTBE units will primarily be used to expand refinery alkylate production. The economics of conversion to iso-octane production makes this less likely within refineries. Refiners could expand alkylate production using more C_3 or C_5 olefins not currently being alkylated, but most refiners do not see that occurring based on current alkylate economics.

MTBE also is currently produced in large commercial plants outside of refineries. In contrast to refineries, the commercial plants do not have a captive source of olefin feedstocks, and thus have a much different production cost structure. These plants could be converted to iso-octane or alkylate production with additional capital investment. Based on discussions with commercial MTBE facility owners, only a small fraction of commercial capacity is expected to be converted. MTBE has always had a significant premium over gasoline (22 cents per gallon on average over the past year), which exceeds alkylate's premium (14 cents per gallon on average over the past year). Most MTBE plant owners doubt that the price premium for alkylate or iso-octane will be sufficient in the long run to provide an adequate return for them to risk the large capital investments required. Most of the capacity that will produce iso-octane will likely come from plants now producing MTBE as a by-product of propylene oxide production, but even in these cases, export of MTBE will be considered before deciding to invest in conversion to iso-octane production.

Appendix D. Petroleum Administration for Defense District (PADD) Definitions



PADD 1
Connecticut, Delaware, District of Columbia, Florida, Georgia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, North Carolina, Pennsylvania, Rhode Island, South Carolina, Vermont, Virginia, West Virginia

PADD 2
Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, Oklahoma, South Dakota, Tennessee, Wisconsin.

PADD 3
Alabama, Arkansas, Louisiana, Mississippi, New Mexico, Texas

PADD 4
Colorado, Idaho, Montana, Utah, Wyoming

PADD 5
Alaska, Arizona, California, Hawaii, Nevada, Oregon, Washington