Timing of Startups of the Low-Sulfur and RFS Programs

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Contacts

This report was prepared by the Office of Oil and Gas of the Energy Information Administration. General questions concerning the report may be directed to Mary J. Hutzler (202/586-2222, mhutzler@eia.doe.gov), Director, Office of Integrated Analysis and Forecasting, or Joanne Shore (202/586-4677, joanne.shore@eia.doe.gov), Team Leader, Petroleum Division

Timing of Startups of the Low-Sulfur and RFS Programs

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 5 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. The *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

The Renewable Fuel Standard (RFS) program is proposed to begin in January 2004. Most refineries must comply with the 30 parts per million (ppm) low-sulfur gasoline standards beginning in January 2005, and ultra-low-sulfur diesel fuel beginning in June 2006. In light of the recent implementation of the Mobile Source Air Toxics rule (MSAT) and evolving State MTBE (methyl tertiary-butyl ether) bans, Sen. Bingaman asked EIA if shifting the startup dates of these future fuel programs would improve the potential for a smooth transition from a supply perspective. This question focuses on whether supply problems could be reduced during the startup phases of these programs through timing changes.

Generally, fuel regulatory timing issues fall into three categories:

1) *Setting implementation dates within an annual calendar*. For example, should the date be set at a time when refiners are making a normal seasonal product change or during a low demand season (e.g., winter for gasoline)? The goal is to try to minimize the potential for supply problems and price surges when new requirements are implemented.

2) *Synchronizing a regulatory change that has a logical connection with other regulatory changes affecting product quality requirements*. An example is the relationship between potential MTBE bans and a waiver to the oxygenate requirement [1] in reformulated gasoline (RFG). The oxygenate waiver gives refiners more flexibility to meet RFG requirements. When the use of MTBE is restricted, refiners will have to make some significant changes, and providing suppliers with as much flexibility as possible during such changes can help smooth the transition. Thus, even though most MTBE-banned +RFG is expected to be made with ethanol initially, having an oxygenate waiver precede or coincide with MTBE ban dates allows as much supply flexibility as possible to minimize chances of product shortfalls.

3) *Allowing an adequate planning and implementation period for large changes, such as large capital investments.* There are three dimensions to consider when large changes are involved. First, adequate time must be allowed to promulgate the regulations. The time required in this case will vary with the complexity of the changes required by the legislation. Second, adequate advance notification must be provided to refiners so that they have time to plan and make the necessary investments. Third the timing must not be so short as to strain the construction and engineering sector such that costs become inflated, thereby adding excessive burden to refiners.

This particular issue deals mainly with the last two aspects of timing, synchronization with other regulations and the size of the changes required. The next subsection provides an overview of the main elements of the low-sulfur and RFS regulations needed to understand how timing changes might affect the programs' start-up success. That is followed by a description of the information and logic used to reach this paper's conclusions.

Background on Low-sulfur Regulations, RFS, and Related Regulations

As a part of the Clean Air Act Amendments of 1990, the U.S. Environmental Protection Agency (EPA_ finalized Tier 2 standards[2] for emissions from light duty vehicles in

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[1] Currently, RFG is required to contain at least 2 percent oxygen by weight. Oxygenates are materials with high oxygen content, such as ethers or alcohols. MTBE, which is an ether, generally has been the most economic oxygenate to use. Ethanol, an alcohol, has been used widely in the Midwest, where fuel ethanol is produced.

[2] U.S. Environmental Protection Agency, *Control of Air Pollution from New Motor Vehicles: Tier 2 Motor*

February 2000. Tier 2 requirements represent a reduction in emissions from the Tier 1 standards that had been in place since the 1994 model year for light duty vehicles. The final Tier 2 rule placed tighter emission standards on both vehicles and fuel. Since most light-duty vehicles use gasoline, the Tier 2 standard required that gasoline sulfur content be reduced because sulfur in gasoline affects vehicle control systems (in particular it interferes with catalyst performance) and increases emissions of hydrocarbons and nitrogen oxides. The final rule required that by the beginning of 2005, refiners must produce, on average, gasoline with sulfur levels no greater than 30 ppm. A sulfur averaging, banking, and credit trading program is included to give refiners flexibility in meeting the standards.

The Final Rule on Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements[3] was designed by EPA as part of a systems approach to reduce emissions from heavy-duty engines and vehicles. The rule requires year 2007 heavy-duty highway engines and vehicles to be equipped with high-efficiency exhaust/emission control systems, which will significantly reduce all emissions. However, the technology would be damaged and made ineffective by high levels of sulfur in the fuel. As a result, the rule includes a requirement for ultra-low-sulfur diesel fuel, which goes into effect on June 1, 2006. The timing requirements for diesel fuel were established to assure adequate ultra-low-sulfur fuel would be available for the model-year-2007 vehicles meeting this rule's emission requirements.

Currently, on-road diesel fuel is required to contain 500 ppm or less of sulfur. The new Highway Diesel Fuel Sulfur Control Rule requires refiners to produce diesel fuel containing no more than 15 ppm sulfur at retail levels by June 2006, which means refiners must produce a product in the 7-10 ppm range to account for contamination during distribution and for testing tolerances – a level 50 times smaller than current requirements. Not only will production of this very-low-sulfur fuel require significant refinery changes, but also, distribution and storage systems and/or procedures will need to be modified to prevent contamination. At such low sulfur levels, exposure to very little additional sulfur can quickly contaminate an entire batch of product.[4]

The two low-sulfur programs require an enormous set of changes for the industry. A study by the National Petroleum Council (NPC)[5] pointed out that the low-sulfur fuel changes for gasoline and diesel fuel affect virtually every refinery and many terminals in the United States, and represent a magnitude of change that is larger than anything that has occurred in the industry before. Investment costs provide a measure of the size of the activities that are involved. The NPC study estimated low-sulfur gasoline specifications

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Vehicle Emissions Standards and Gasoline Control Requirements, 40 CFR Parts 80, 85, and 86 (Washington, DC, February 10, 2000).

[3] U.S. Environmental Protection Agency, "Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements: Final Rule," *Federal Register*, 40 CFR Parts 69, 80 and 86 (January 18, 2001).

[4] Energy Information Administration, *The Transition to Ultra-Low-Sulfur Diesel Fuel: Effects on Prices and Supply*, SR/IOAF/2001-01 (Washington, DC, May 2001).

[5] National Petroleum Council, *U.S. Petroleum Refining - Assuring the Adequacy and Affordability of Cleaner Fuels* (Washington, DC, June 2000).

would require about $8 billion in investments, and EIA's study on ultra-low-sulfur diesel fuel indicated a cost range for this program to be between $6 and $9 billion.[6] That means the industry is facing from $14 to $17 billion investment cost for these two programs.

When the studies on refining costs were being performed, the current Renewable Fuel Standard (RFS) was not being considered. Unlike the low-sulfur fuels regulations that stem from the Clean Air Act Amendments of 1990, the RFS is one of the fuels provisions being proposed in H.R. 4. It focuses on encouraging use of non-petroleum-based fuels by requiring an increasing volume of renewable fuel each year, starting at 2.3 billion gallons in 2004. EPA will assign a renewable volume quota to each gasoline supplier, based on the supplier's gasoline market share, to assure that the target will be met. The first year's RFS volume requirement should not strain the industry. In 2001, the United States was already using 1.7 billion gallons of ethanol. With the California MTBE ban alone, which will result in ethanol use in California reformulated gasoline, the industry is likely to be at or near the RFS target in 2004. (See discussion on Timing for Startup of the Renewable Fuel Standard.)

The RFS will require investment by ethanol producers and at terminals where ethanol is blended into gasoline. The RFS investments, however, will be far less than those required by the low-sulfur fuel programs, since major refinery changes are not required to implement the RFS. One study estimated that to get to the 2012 RFS target of 5 billion gallons of ethanol use, the refining and marketing industry would have to spend $0.4 billion,[7] compared to an estimate to implement the two low-sulfur fuel programs of $14 to $17 billion. While the changes required by the RFS may be small in comparison to the low-sulfur programs, adding one more requirement to refiners on top of an already unprecedented investment and construction program to produce low-sulfur fuels raises the question of strain on availability of supply.

The Mobile Source Air Toxics rule (MSAT)[8], which went into effect in January 2002, caps an individual refinery's gasoline toxic emissions at its historical level during 1998-2000. Thus, refineries that were over-complying with Federal fuel emission regulations are not allowed to backslide. This, by itself, is not a problem. But when refiners have to remove MTBE and add ethanol, the ethanol increases total gasoline toxic emissions, and to comply with MSAT, refiners must reduce those toxic emissions. (See Appendix B for a discussion of MSAT and its interaction with MTBE bans.)

The MSAT/MTBE-ban issue is related to the low-sulfur-gasoline program in that both situations involve reduction of toxics in gasoline. Some State MTBE bans are occurring before the Federal low-sulfur-gasoline program is scheduled to be in place for most

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[6] Energy Information Administration, *The Transition to Ultra-Low-Sulfur Diesel Fuel: Effects on Prices and Supply*, SR/OIAF/2001-01 (Washington, DC, May 2001) p 70.
[7] Downstream Alternatives Inc., *Infrastructure Requirements for an Expanded Fuel Ethanol Industry* (South Bend, IN, January 15, 2002), p. ES-10. Note that the investment cost of $0.4 billion does not include investment costs refiners may need to comply with MSAT from adjusting for any toxic increases arising from the addition of the ethanol. Since the industry will likely be at the RFS requirement by 2004 due to State MTBE bans, these costs were not added to the comparisons in this paper.
[8] *Control of Emissions of Hazardous Air Pollutants from Mobile Sources*, Final Rule, 40 CFR Parts 80, 86.

refineries. The issue of MSAT and MTBE bans, while an important supply issue, does not affect the timing of the Federal low-sulfur gasoline program, but rather suggests States may want to consider delaying their MTBE bans to coincide or occur after the low-sulfur gasoline program is in effect. Synchronizing toxic reduction programs can minimize the potential for cost-inefficient solutions or even temporary supply reductions as refiners try to deal with one program's toxic implications a year or two before those of the next program. While some refiners might be able to begin compliance with the low-sulfur-gasoline program concurrently with State MTBE bans, not all refiners will be able to implement it ahead of schedule because of the size and complexity of the changes required to meet the Federal program. It would be impractical to move the Federal low-sulfur-gasoline program to an earlier startup date. Thus, the only way to coordinate this program with State MTBE bans would be to delay the latter. Since the timing issue for MSAT/MTBE ban issues rests at the State level, it is not discussed further in this paper, but is covered in the question addressing supply implications of MTBE bans.

Findings

Although every additional requirement on top of an already unprecedented set of requirements increases the potential for transition problems in general, the addition of the RFS to the changes being required by the low-sulfur fuel programs should not create a major problem for refiners. It is likely that the industry will produce the first year's RFS volume requirements for ethanol as a result of State MTBE bans that are scheduled to begin in 2004. Thus, the industry is likely to comply without major transition problems.

EIA has found no information to suggest that a delay in the low-sulfur gasoline program would ease the startup transition. The key findings of the NPC study in 2000 were that implementing the low-sulfur gasoline program by 2005, while taxing the industry during the peak workload period, could be accomplished. Furthermore, with the low-sulfur gasoline program scheduled to begin 3 years from now, many refiners are already executing their plans to meet the requirements, and, as such, it does not seem advisable to shift this schedule.

The ultra-low-sulfur diesel fuel program, on the other hand, is still problematic for many refiners. The magnitude of the ultra-low-sulfur diesel fuel implementation workload and investments is expected to be large, following the large investments of the low-sulfur gasoline program. The issue is not only affordability on the part of refiners, but also strain on the construction and engineering firms that will make the changes. The NPC study pointed out that the short time between implementation of these two programs would likely result in "construction worker shortages, longer and more costly schedules for both programs, and severe permitting delays."[9]

Unlike low-sulfur gasoline, refiners generally have a choice when producing distillate

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[9] National Petroleum Council, *U.S. Petroleum Refining - Assuring the Adequacy and Affordability of Cleaner Fuels* (Washington, DC, June 2000), Summary Section.

fuel.[10] Nearly all refiners must produce gasoline if they are to stay in business, but a refiner does not necessarily have to produce on-road diesel fuel, which is what the ultra-low-sulfur diesel fuel program regulates. Refiners can produce only high-sulfur distillate fuel that is used in home heating, electricity generation and other off-road applications. This would allow some refiners the option of waiting until they can determine how the market and technologies will evolve. EIA's study[11] on this matter showed that the variation in cost to comply with the diesel fuel rule was large among different types of refineries. With widely varying investment costs, one could expect some of the high-cost refiners to delay investing in ultra-low-sulfur diesel fuel production for competitive reasons. Refiners facing very high costs risk losing much more money than lower-cost refiners if technologies change or the market is over-supplied initially. In addition, several large uncertainties remain that could affect refiners' investment decisions: the requirements for off-road diesel fuel, and further specification changes that may be required for on-road diesel fuel, such as further cetane or aromatics restrictions. If enough refiners postpone production of ultra-low-sulfur diesel fuel, supply could be inadequate at the beginning of the program.

The dilemma is that this regulation has disparate effects on different refiners. As explained in the EIA study on the impacts of changing to ultra-low-sulfur diesel fuel, the magnitude of change that refining companies must make depends on their current feedstocks, configurations, size, and competitive situation. A delay in the timing and/or reduction in the initial magnitude of compliance required could provide some relief to refiners just coming off of a large investment program for low-sulfur gasoline and reduce the potential for a supply shortfall during the transition. The new technologies involved in this program and the magnitude of investments required will be easier for some refiners to deal with than others. Complicating the issue, timing must take into consideration that this regulation was meant to coincide with heavy-duty-vehicle requirements beginning in model-year 2007 and to assure that adequate fuel would be available for these new vehicles.

Conclusion

The question from the Sen. Bingaman was whether changing startup timing for the RFS and low-sulfur fuel programs could ease the transition to these new programs to reduce the potential for supply shortages and price volatility. Because of impending States MTBE bans, the close introduction of the RFS and low-sulfur gasoline programs should not create a large problem. The industry will likely be meeting RFS requirements in 2004 when the RFS program is scheduled to start due to the State MTBE bans, so there does not seem to be a need to shift the relative startup dates between the RFS and the

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[10] Distillate refers to both on-road quality low-sulfur diesel fuel and No. 2 distillate fuel oil used in home heating, electricity generators and other off-road applications. Prior to the sulfur requirement for on-road diesel fuel, the two fuels were virtually identical and only needed to be segregated for tax purposes.
[11] Energy Information Administration, *The Transition to Ultra-Low-Sulfur Diesel Fuel: Effects on Prices and Supply*, SR/OIAF/2001-01 (Washington, DC, May 2001), Chapter 5.

low-sulfur gasoline programs. In fact, ethanol capacity in 2004 is expected to exceed the RFS requirement. With the low-sulfur gasoline program due to begin 3 years from now, many refiners are already executing their plans to meet the program. As such, it does not seem necessary to shift schedules. The program that still may need consideration for altering the timing or startup requirements is the ultra-low-sulfur diesel fuel program. The magnitude of changes required for both the gasoline and diesel fuel programs and the outstanding issues that will affect diesel fuel production plans, such as requirements for off-road diesel fuel, need to be studied to ensure adequate supply during the transition. However, any proposal to change the timing of the ultra-low-sulfur diesel fuel program must take into account synchronization with the heavy-duty vehicle changes required in model year 2007.

Appendix A. Request from Committee and EIA Interim Response

<u>Request from Committee</u>

United States Senate

COMMITTEE ON
ENERGY AND NATURAL RESOURCES
WASHINGTON, DC 20510–6150

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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

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. Mobile Source Air Toxic Rule Interaction with MTBE Bans

The Mobile Source Air Toxics rule (MSAT)[12] would not be a major problem if MTBE were to remain a key component of RFG in the future. But MSAT, when combined with possible MTBE bans, has become an issue, and illustrates the interconnected nature of fuel quality decisions. MSAT, which went into effect January 2002, identified compounds to be considered as mobile source air toxics and established new toxic emission gasoline baselines for individual refineries using the baseline period 1998-2000. These baselines "maintain current levels of over-compliance with toxic emissions performance standards that apply to Federal reformulated gasoline (RFG) and anti-dumping standards that apply to conventional gasoline (CG)."[13] Thus, the MSAT rule is also sometimes referred to as the "anti-backsliding" regulation. EPA notes in the rule that since an historically achieved baseline is being used, refiners are not required to install new equipment or use different technologies from those used during the baseline years, and therefore the program should have little cost. EPA's assumption about program costs is valid when the future doesn't change from history. But MTBE bans are changing the future from the past, and MTBE was a vital clean-gasoline component for many refiners during the baseline years.

MTBE bans create a disproportionate impact on some refineries that historically had used MTBE, had very low toxic baselines, and produced high fractions of reformulated gasoline compared to conventional. To understand the effect on different refineries, it is necessary to understand some features of the MTBE bans. MTBE has a high oxygen content, is relatively clean burning, and has high octane. MTBE is used mostly in reformulated gasoline (RFG), where the oxygen requirement of the Clean Air Act Amendments of 1990 and its clean burning properties made it a very attractive material. There are no easy substitutes for the volumes of MTBE being lost. Ethanol is one of the materials many refiners will use to replace the MTBE volumes being lost. But while ethanol has good octane characteristics and is relatively clean compared to many gasoline components, it has higher toxics emissions than MTBE (Appendix C).

Refiners needing to reduce toxics can do so by adding isomerization processes (which significantly reduce benzene content) and sulfur removal equipment (which reduces exhaust benzene). But some refiners using MTBE have already made refining changes to reduce sulfur and benzene in their gasoline. As a result, 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. They will need to opt for reducing their production of RFG, incorporating their cleanest streams, and leaving the remaining material for use in conventional gasoline, if that product can absorb the material and not exceed anti-dumping and MSAT requirements.

The refiners with the largest problem seem to be some of those serving the East Coast

[12] *Control of Emissions of Hazardous Air Pollutants from Mobile Sources*, Final Rule, 40 CFR Part 80,86.
[13] Ibid., Summary section.

that have very low RFG toxics baselines and that produce mostly RFG and little conventional gasoline. The percentage of conventional gasoline can be important because conventional gasoline would frequently have a higher toxic content than RFG and has little or no MTBE to be replaced. Some refiners may be able to produce more conventional gasoline by removing some of the problematic components from RFG to balance the ethanol toxic effects, placing them in the conventional pool. In the case where a refinery is producing 80 percent conventional and 20 percent RFG, it may be possible to remove some toxic material from the 20 percent RFG volume and move it to the 80 percent conventional volume without impacting conventional gasoline's MSAT restriction. But when the refinery produces 80 percent RFG and 20 percent conventional gasoline, the small-volume conventional pool may not be able to absorb all the materials being removed from the 80 percent RFG pool without adversely affecting the quality of the conventional gasoline.

Some very clean refiners serving the East Coast have indicated that they may have to reduce the volumes of RFG they produce as a result of the MSAT restrictions in conjunction with the MTBE bans. The result of such reductions on the East Coast may be that "dirtier" refineries from the Gulf Coast or "dirtier" import sources will be filling in the volumes that the "cleaner" refineries on the East Coast are no longer producing.

Refineries in California producing California RFG (CaRFG) are exempt from the MSAT, and refineries in PADD 2 producing RFG were using ethanol when their baseline was established, so they should not be affected. At this time, it does not appear that the Gulf Coast refineries are being constrained to the same degree as those on the East Coast.

Appendix C. Ethanol and MTBE Emissions Comparison

The different properties of ethanol and MTBE cause refiners to have to make further investments in order to achieve the same level of toxic emissions reduction when switching from using MTBE to ethanol in reformulated gasoline. This section provides a comparison to better understand the issues. The complex formula developed by EPA is used to determine the emission characteristics of reformulated gasoline. It is based on empirical data that related various emissions to gasoline properties. Refiners use this model to develop gasoline blends that will meet the Federal RFG requirements.

Federal reformulated gasoline requirements for the most part are stated in terms of emission reductions required from an industry base gasoline that is defined in the final rule. Table 1 shows the properties of that base gasoline, and in the far right column, it shows what reductions are necessary from that baseline gasoline to meet reformulated gasoline requirements.

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 VOC's are almost 26 percent lower than the industry baseline fuel, toxics are over 33 percent lower, and NOx emissions are reduced by about 8 percent. The Federal requirements are shown in the far right column. The Table shows that the MTBE blend far exceeds Federal requirements in everything except VOC's, where it just meets that requirement.

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.

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, 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 VOC's within Federal limits. Although the toxics are within reformulated gasoline requirements, they violate MSAT for this refiner. The toxics in the 5.8 percent ethanol case at 61.4 milligrams per mile (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. This refiner, when switching from MTBE RFG to ethanol-blended RFG, would have to make further refinery 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 NOx fall within the Federal RFG requirements, while VOC emissions exceed Federal 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, for example. 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 in total.

Table 1. 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.

Glossary of Terms

Alkylate: The product of an alkylation reaction. It usually refers to the high-octane product from alkylation units. This alkylate is used in blending high-octane gasoline.

Alkylation: A refining process for chemically combining isobutane with olefin hydrocarbons (for example, propylene, butylenes) through the control of temperature and pressure in the presence of an acid catalyst, usually sulfuric acid or hydrofluoric acid. The product, alkylate, an isoparaffin, has high-octane value and is blended with motor and aviation gasoline to improve the anti-knock value of the fuel.

Aromatics: Hydrocarbons characterized by unsaturated ring structures of carbon atoms. The basic ring has six carbon atoms and is shaped like a hexagon. Some heavier aromatics with two or more hexagonal rings with common sides (polycyclic aromatics) are also present in gasoline; some are formed during combustion. Some aromatics are ozone forming; some are toxic. Benzene and polycyclics are toxic; xylenes and some of the more complex aromatics are active ozone formers. Commercial petroleum aromatics are benzene, toluene, and xylene.

Benzene: A hydrocarbon of the composition C_6H_6 and the initial member of the aromatic or benzene series. Its molecular structure is conceived as a ring of six carbon atoms with double linkage between each alternating pair and with hydrogen attached to each carbon atom. Benzene is a minor constituent of most crude oils and is produced mainly by the catalytic reforming of petroleum naphthas and from the various cracking processes. Benzene is a toxic compound.

Cut: A cut is a fraction of the charge stock separated by distillation. For example, kerosene is a cut of crude oil.

Normal Butane (C_4H_{10}): A normally gaseous straight-chain hydrocarbon. It is a colorless paraffinic gas that boils at a temperature of 31.1 degrees Fahrenheit. It is extracted from natural gas or refinery gas streams.

E200: Percent of fuel evaporated below 200 degrees Fahrenheit, as determined by ASTM distillation test D86.

E300: Percent of fuel evaporated below 300 degrees Fahrenheit, as determined by ASTM distillation test D86.

Isomerization: A refinery process which converts normal or straight chain hydrocarbons that have a poor octane quality into high-octane branch chain isomers. Thus, n-butane is converted into isobutane, etc.

NO_x—Nitrogen Oxides: Chemical compounds containing nitrogen and oxygen; reacts with volatile organic compounds in the presence of heat and sunlight to form ozone. It also contributes to acid rain.

Octane Number: A number used to indicate gasoline's antiknock performance in motor vehicle engines. The two recognized laboratory engine test methods for determining the antiknock rating, i.e., octane rating of gasoline, are the Research method and the Motor method. To provide a single number as guidance to the consumer, the antiknock index (R + M) /2, which is the average of the Research and Motor octane numbers, was developed.

Olefins: Olefins are highly reactive unsaturated compounds (that is, the carbon atoms in the molecule are able to accept additional atoms such as hydrogen or chlorine). Some are present in gasoline as a result of refinery manufacturing processes such as cracking. Some are created in the engine during combustion; most of these can be removed in the catalytic converter. They tend to be ozone formers and toxic.

Reformate: The product of the reforming process which runs at high temperature with a catalyst to convert paraffinic and naphthenic hydrocarbons into high octane stocks, primarily aromatics suitable for blending into finished gasoline.

Reid Vapor Pressure (RVP): A measure of product volatility, measured in pounds per square inch (psi). The higher the RVP, the more volatile a gasoline is and the more readily it evaporates.

T50: The temperature at which 50 percent of fuel has vaporized.

T90: The temperature at which 90 percent of fuel has vaporized.

Volatile Organic Compounds (VOCs): Organic compounds which participate in atmospheric photochemical reactions.