POTENTIAL SUPPLY AND COST IMPACTS OF LOWER SULFUR, LOWER RVP GASOLINE

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TABLE OF CONTENTS

I. ABSTRACT

A proposal has been made by the Alliance of Automobile Manufacturers for a single national (excluding California) summertime gasoline specification that they referred to as National Clean Gasoline (NCG). NCG, as proposed, would require significantly lower sulfur limits than current United States gasoline and, for much of the nation, also significantly lower limits on Reid vapor pressure (RVP).

This report examines four potential scenarios with lower sulfur and lower RVP requirements than current gasoline specifications. In two, summertime RVP is reduced nationwide (excluding California) to 7 pounds per square inch absolute (psia). In the other two, summer time RVP's are limited to 7.8 psia and 8.8 psia (including a 1 psia waiver for ethanol blending) in regions that currently allow the waiver for conventional gasoline. Reformulated gasoline (RFG) maintains an RVP of 7.0 psia. In three of the cases, sulfur in individual batches is limited to 20 parts per million (ppm) with a company annual average limit of 10 ppm. In one case, the sulfur limits are 10 and 5 ppm, respectively.

The results of the analysis show that four to seven refineries are likely to shut down rather than make the necessary investments to produce gasoline with lower sulfur and lower RVP specifications. A substantial volume of domestically-produced light hydrocarbon currently blended into gasoline would be removed from gasoline and would be sold into other markets. Total domestically-produced gasoline (excluding ethanol) is estimated to decrease by 0.6 to 1.3 million barrels per day during the summer. If gasoline consumption remains at Base Case levels, gasoline imports would more than double in three of the cases, leaving the U.S. more exposed to supply disruptions. Annualized marginal compliance costs for U.S. refineries are estimated in the range of 12 to 25 cents per gallon. Summer-only costs are nearly double that of annualized costs. Additional hydrotreating and fractionation required to comply would result in an

increase in carbon dioxide (CO_2) emission from refineries that continue to operate. On an annual average basis, the total increase in CO_2 emissions at domestic and foreign refineries is estimated at 2.9 to 7.4 million tonnes per year.

II. INTRODUCTION

In 2009, the Alliance of Automobile Manufacturers published a report[1] (the AAM Report) documenting purported costs and benefits of a single national standard for gasoline quality that would apply to all states except California. The AAM Report calls the new gasoline standard "National Clean Gasoline." The American Petroleum Institute (API) engaged Baker and O'Brien, Inc. (Baker & O'Brien) to perform an independent analysis to determine the potential supply and cost impacts of lowering the specifications for sulfur and RVP in gasoline. This study was prepared by Baker and O'Brien using its own models and analysis.

General industry conditions, corporate profiles, geographic considerations, and unique refinery characteristics can influence potential responses to regulatory requirements. Therefore, Baker & O'Brien undertook a refinery-by-refinery approach in evaluating the potential impacts of lowering the specifications for sulfur and RVP in gasoline. Compliance options were evaluated and production estimates calculated for each refinery using Baker & O'Brien's *PRISM*™ Refining Industry Analysis modeling system. The *PRISM* model is based on publicly-available information, and incorporates Baker & O'Brien's industry experience and knowledge.

Baker & O'Brien conducted this analysis and prepared this report with reasonable care and skill, utilizing methods we believe to be consistent with normal industry practice. No other representations or warranties, expressed or implied, are made by Baker & O'Brien. All results and observations are based on information available at the time of this report. To the extent that additional information becomes

[1] Alliance of Automobile Manufacturers, "National Clean Gasoline: An Investigation of Costs and Benefits," June 2009.

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available or the factors upon which our analysis is based change, our opinions could be subsequently affected.

III. EXECUTIVE SUMMARY

In 2009, the Alliance of Automobile Manufacturers published a report[2] (the AAM Report) documenting purported costs and benefits of a single national standard for gasoline quality with significant reductions in sulfur and Reid vapor pressure (RVP) that would apply to all states except California. The AAM Report calls the new gasoline standard "National Clean Gasoline."

The American Petroleum Institute (API) engaged Baker and O'Brien, Inc. (Baker & O'Brien) to perform an independent analysis to determine the potential supply and cost impacts of lowering the specifications for sulfur and RVP in gasoline. A refinery-by-refinery analysis was performed that considered each refinery's compliance options accounting for technical, strategic, market, and economic factors, and then estimated a likely response based on this information. It is believed this approach is superior to aggregate or notional-type modeling, given the likely variation in refinery response to regulation, based on each refinery's unique position.

Implementing a nationwide (except California) summer season 7 pounds per square inch (psia) RVP specification and sulfur limits of 20 parts per million (ppm) per gallon cap and 10 ppm company annual average (the Study Case) would remove a large quantity of natural gas liquids (NGLs)[3] from gasoline. Our modeling indicates that domestic gasoline production would decrease by 1,157 thousand barrels per calendar

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[2] Alliance of Automobile Manufacturers, "National Clean Gasoline: An Investigation of Costs and Benefits," June 2009.

[3] NGLs refer to a class of hydrocarbons in natural gas that are separated from the gas as liquids. NGLs include ethane, propane, butane, isobutane, and "Pentanes Plus." Pentanes Plus is a term used by the U.S. Department of Energy to describe a mixture of mainly pentanes and heavier hydrocarbon which may contain some butanes and which is obtained from the processing of raw natural gas, condensate or crude oil. The term "Pentanes Plus" is sometimes used interchangeably with the terms condensates and natural gasoline. These hydrocarbons are also produced in refineries, and in this report the term NGLs is used to describe these hydrocarbons regardless of the source.

day (MB/CD) during the summer,[4] this is equivalent to 14 percent (%) of projected summer 2016 hydrocarbon gasoline consumption.[5] If gasoline consumption remains at Base Case levels, summer gasoline imports would need to increase by 125% from 923 MB/CD in the Base Case to 2,080 MB/CD in the Study Case. It is not clear that this volume of gasoline with lower sulfur and lower RVP would be available from foreign refineries, and United States (U.S.) vulnerability to supply disruptions is obviously much greater in the Study Case.

Three Sensitivity Cases were also examined. In the first, even lower sulfur limits were imposed, and the modeling indicates a further reduction in domestic gasoline production and a still greater need for imports. In the other two, sulfur levels were the same as in the Study Case and RVP limits were relaxed slightly in some regions. The relaxation of RVP limits in these cases increased gasoline production relative to the Study Case, but the lost gasoline production relative to the Base Case was still significant.

Domestic refinery investment costs for implementing the lower sulfur and lower RVP standards considered range from $10 to $17 billion.[6] Based on investment-decision criteria described below, four to seven refineries would likely shut down rather than make the required investments. There are additional investments that would be required outside the refineries that are not included in these totals. On an annual basis, total domestic refining industry compliance costs are estimated at $5 to $13 billion.

Additional hydrotreating and fractionation required to comply would result in an increase in carbon dioxide (CO_2) emissions from refineries that continue to operate. On

[4] The analysis divided the year into two seasons. In this report, “summer” includes the months April through September inclusively. “Winter” is the remaining six months.
[5] Changes in gasoline production and imports throughout the report are hydrocarbon only. It was assumed that domestic ethanol production and consumption remain constant at Base Case levels.
[6] All costs in this report are expressed in constant 2009 U.S. Dollars.

an annual average basis, the total increase in CO_2 emissions at domestic and foreign refineries is estimated at 2.9 to 7.4 million tonnes per year.

These results are significantly different than those reported in the AAM Report. While a detailed reconciliation was not performed, there are several obvious differences in approach. The refining section of the AAM Report only considered refineries in PADDs 1, 2, and 3. According to the AAM Report, modeling was done using three aggregate refinery models, one for each of these PADDs.[7] Our analysis was done with individual models of 112 refineries, including refineries in PADDs 4 and 5. As noted in the AAM Report, the aggregate modeling approach may lead to "over-optimization" and an understatement of compliance costs.[8]

The AAM Report does not appear to consider the lost value of NGLs that would be removed from the gasoline pool, and their estimate of the volumes that would be removed appear to be much smaller than what is reported herein. The AAM Report assumes that many refineries already have the capability to produce 5 ppm sulfur gasoline.[9] Our analysis indicates that most will require capital investments to produce 5 or 10 ppm sulfur gasoline. The AAM Report also uses a capital cost estimate for new fluid catalytic cracker (FCC) gasoline hydrotreater capacity that is approximately 25% of the figure used in this report.[10] The AAM analysis does not appear to include FCC feed hydrodesulfurization revamps, expansions, or new units. These items were included in this analysis.

[7] Alliance of Automobile Manufacturers, "National Clean Gasoline: An Investigation of Costs and Benefits," June 2009, p.1-2.
[8] Ibid, p. 1-23.
[9] Ibid, p.1-19.
[10] Ibid, p.1-19.

REGULATORY ASSUMPTIONS

The Base Case in this analysis assumes that all existing fuel regulations based on existing law are fully implemented. The Study Case assumes that a lower sulfur and lower RVP standard with a nationwide (excluding California) RVP limit of 7 psia and sulfur limits of 20 ppm on individual batches and 10 ppm company annual average is implemented. Three Sensitivity Cases were also analyzed. A comparison of the key gasoline specifications in those cases and those proposed in the AAM Report is shown below. All other gasoline specifications were assumed to remain unchanged.

Regulatory Assumptions

<table>
<tr><th colspan="3" rowspan="2">Property</th><th rowspan="2">Base Case</th><th rowspan="2">Study Case</th><th colspan="3">Sensitivity Cases</th><th rowspan="2">AAM Study</th></tr>
<tr><th>Case 1</th><th>Case 2</th><th>Case 3</th></tr>
<tr><td colspan="2" rowspan="2">Sulfur, maximum ppm</td><td>Company annual average</td><td>30</td><td>10</td><td>5</td><td colspan="2">10</td><td>10*</td></tr>
<tr><td>Individual batch</td><td>80</td><td>20</td><td>10</td><td colspan="2">20</td><td>*</td></tr>
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<tr><td>1 psia Waiver</td></tr>
<tr><td rowspan="2">Benzene, maximum Vol.%</td><td colspan="2">Company annual average</td><td colspan="6">0.62</td></tr>
<tr><td colspan="2">Refinery annual average</td><td colspan="5">1.3</td><td>*</td></tr>
<tr><td colspan="2" rowspan="2">Octane, minimum (R+M)/2</td><td>Regular</td><td colspan="5" rowspan="2">Varies regionally</td><td>87</td></tr>
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<tr><td colspan="2" rowspan="2">ASTM Driveability Index (DI), maximum***</td><td>Summer</td><td colspan="5" rowspan="2">Varies regionally</td><td>1,250*</td></tr>
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* It is not clear from the AAM Report how the sulfur, RVP, and ASTM DI maximums would be applied. A blending limit of 5 ppm, 6.8 psia, and 1,220 for sulfur, RVP, and DI, respectively, was reportedly used in the refinery modeling work. It is also not clear what volatility limits would apply during the non-summer seasons or if the refinery annual average for benzene would remain unchanged.

**RVP limited to 7.0 psia in current RFG areas and other areas currently requiring 7.0 psia. RVP limited to 7.8 psia in all other regions except California.

*** No units apply, but in this context, temperatures are measured in degrees Fahrenheit (°F).

Most of the analysis described in this report was completed before the Environmental Protection Agency (EPA) approval of a gasoline formulation with 15% ethanol for late-model automobiles. Because of the uncertainty in what specifications for motor gasoline containing more than 10% ethanol might be, it was assumed that the 10% limit would remain in place on all motor gasoline other than E85.[11] The analysis is, therefore, focused on the impact of the potential lower sulfur and lower RVP specifications, and complications related to changes in ethanol content are avoided.

TECHNOLOGY AND INVESTMENT COSTS

There are significant differences in gasoline sulfur and summer RVP specifications between the Base, Study, and Sensitivity Cases. The summer RVP limits in the Study and Sensitivity Cases would require removal of additional low boiling point, high RVP blendstocks from the gasoline pool at many refineries. New fractionation towers would be required at many refineries to accomplish this.

To reduce sulfur in finished gasoline, further reductions in FCC gasoline sulfur would be required. The Tier 2 gasoline regulations that took effect in 2004 caused almost all refiners to lower FCC gasoline sulfur by desulfurizing FCC gasoline and/or FCC feed. Additional reductions would be required to meet the Study and Sensitivity Cases' sulfur standards. This would require a combination of new desulfurization units and revamps and expansions of existing units.

New or expanded loading and unloading facilities (storage tanks, piping, vapor recovery systems, pumps, rail car loading spots, etc.) would be required at refineries to handle the volume of NGLs that would be extracted and sold as a result of lower summer RVP specifications. The scope of such modifications would vary by refinery and depends on a refiner's existing loading/unloading infrastructure and capability.

[11] E85 refers to a gasoline-ethanol blend containing a nominal 85% ethanol by volume.

Transportation of the displaced surplus NGLs would be a challenge. Much of this material would need to be shipped in special-purpose rail cars. Additional rail cars, storage, and handling facilities would be required.

ANALYTICAL BASIS

Each refinery is unique, given its current technology, location, product slate, etc. Therefore, a refinery-by-refinery analysis was performed that considered each refinery's compliance options accounting for technical, strategic, market, and economic factors, and then estimated a likely response based on this information. It is believed this approach is superior to aggregate or notional-type modeling, given the likely variation in refinery response to regulation, based on each refinery's unique position.

Baker & O'Brien's proprietary *PRISM*™ Refining Industry Analysis modeling system was used extensively throughout this study. The *PRISM* system includes a sophisticated, mass-balanced refinery simulator and models of virtually every refinery in North America.

The Study Case summer RVP requirement would cause many refineries to produce additional NGLs that cannot be blended in gasoline. A surplus of NGLs would likely be resolved through a combination of a number of actions including:

- A reduction in butane and/or pentane imports;
- Substitution of butane and/or pentane for other chemical industry feedstock;
- An increase in butane and/or pentane exports to foreign markets;
- Consumption or sales of butane and/or pentane as fuel or as feedstock for hydrogen production;
- Alkylation of FCC Pentanes;[12] and
- Seasonal stockpiling of NGLs.

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[12] The term FCC Pentanes refers to the mix of 5-carbon molecules produced from an FCC unit and includes C5 olefins and di-olefins.

The quantity of NGLs that would need to be removed from gasoline during the summer in both the Study and Sensitivity Cases is quite large. This would have a significant impact on the value of these hydrocarbons. Because the incremental or lowest value market for the surplus NGLs would be a substitute for natural gas, that portion of the displaced NGLs would have to compete with natural gas. Refiners selling these hydrocarbons into that market would only realize a value roughly equivalent to natural gas. Using a pricing scenario consistent with Annual Energy Outlook 2010 (AEO 2010), this value is significantly less than the value as gasoline blendstocks. This lost value has been treated as a cost to refiners, in addition to the investment and operating costs required to meet the gasoline specifications in the Study and Sensitivity Cases.

A stepwise refinery-by-refinery approach was utilized in analyzing compliance options. If the investment required at any refinery exceeded its value as an ongoing concern (assumed to be five times the future annual net cash flow), then it was assumed that the refinery would stop making gasoline and/or shut down.

The demand side response to the Study and Sensitivity Case scenarios has not been analyzed. Gasoline consumption has been held constant in all Cases. Imports in the Base Case are consistent with the AEO 2010 Reference Case and history. The availability of imports to meet the requirements of the other Cases was not assessed.

STUDY RESULTS

In the Base Case, U.S. refiners are projected to supply 7,435 MB/CD of gasoline during the summer, meeting 87% of the domestic requirement in 2016. Non-refinery domestic gasoline production is estimated to be 200 MB/CD, and 923 MB/CD of imported gasoline (excluding ethanol) would be required to meet the summer U.S. consumption forecast of 8,558 MB/CD. Foreign refiners have supplied the U.S. market with this magnitude of gasoline in recent years, but the ability of foreign refineries to supply the 2016 requirements was not analyzed.

In the Base Case, 112 refineries were producing non-California gasoline (including some California refineries). In the Study Case and Sensitivity Cases 2 and 3, it was projected that four refineries would likely shut down rather than make the investments required to comply with the lower sulfur and lower RVP specifications. In Sensitivity Case 1 the number of refineries that are projected to shut down increases to seven. These refineries are projected to have the potential to make 110 MB/CD of gasoline with lower sulfur and lower RVP in the Study Case, 170 MB/CD in Sensitivity Cases 2 and 3, and 206 MB/CD in Sensitivity Case 1 if they did make the investment. The estimated compliance investments for the remaining refineries (net of shutdowns) are shown below.

Expected Refinery Compliance Investments

	Study Case	Sensitivity Case 1	Sensitivity Case 2	Sensitivity Case 3
Refinery Shutdowns	4	7	4	4
Number of New Units				
Naphtha Depentanizer	45	43	27	16
FCC Depentanizer	40	38	9	9
Hydrocracker Depentanizer	23	22	2	2
FCC Feed Hydrotreater	1	8	1	1
FCC Gasoline Hydrotreater	9	20	9	9
Number of Revamps and Expansions				
FCC Feed Hydrotreater	30	28	27	27
FCC Gasoline Hydrotreater	32	38	30	30
Logistics/Tankage, $MM	977	1,114	609	366
Total Investment Cost, $MM	11,488	17,343	9,957	9,577

Note: Individual refineries may appear in multiple categories for each case.

To meet the Study and Sensitivity Case summer RVP specification, 315 to 934 MB/CD of NGLs would be removed from the gasoline blend pool. In the Study Case, the resulting decrease in summer refinery gasoline production is estimated at 1,157 MB/CD versus (vs.) the Base Case. This is equivalent to 14% of projected 2016 summer hydrocarbon gasoline consumption. In Sensitivity Case 1 the lost production increases to 1,377 MB/CD of domestic gasoline production. In Sensitivity Cases 2 and 3, the reduction vs. the Base Case is 873 and 622 MB/CD, respectively.

Because refiners are already running at maximum volatility limits during the winter, there is no room to reabsorb the NGLs displaced during the summer into the winter gasoline pool. Other outlets would need to be found. The magnitude of these volumes would likely have a significant impact on the U.S. refining, chemicals, and NGL markets. Investments required by refiners to modify their storage, loading, and unloading facilities to store and transport surplus summer butanes and pentanes are estimated at $400 million (in Sensitivity Case 3) to $1.1 billion (in Sensitivity Case 1). Additional investments would be required outside the refining industry to transport and handle these NGLs.

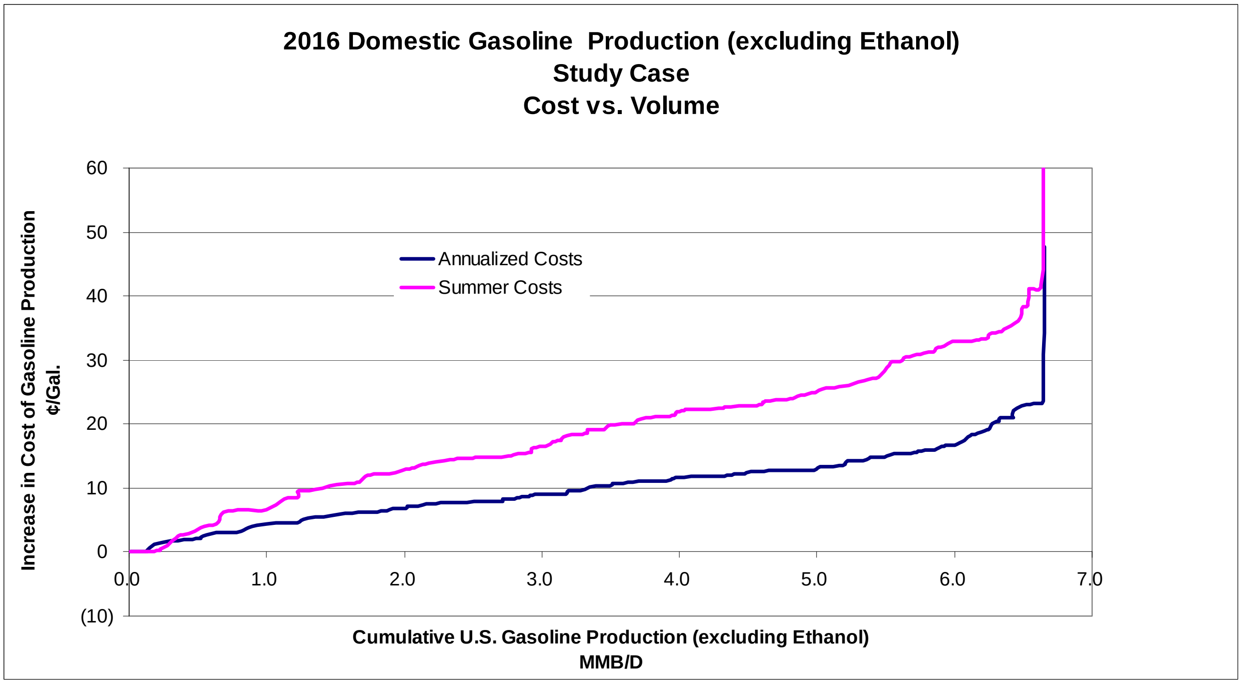
The downgrade in NGLs value is by far the largest compliance cost. Capital investment costs are second. Refinery investment costs range from $9.6 billion (in Sensitivity Case 3) to $17.3 billion (in Sensitivity Case 1). As mentioned, there are additional investments that would be required outside the refineries that are not included in these totals.

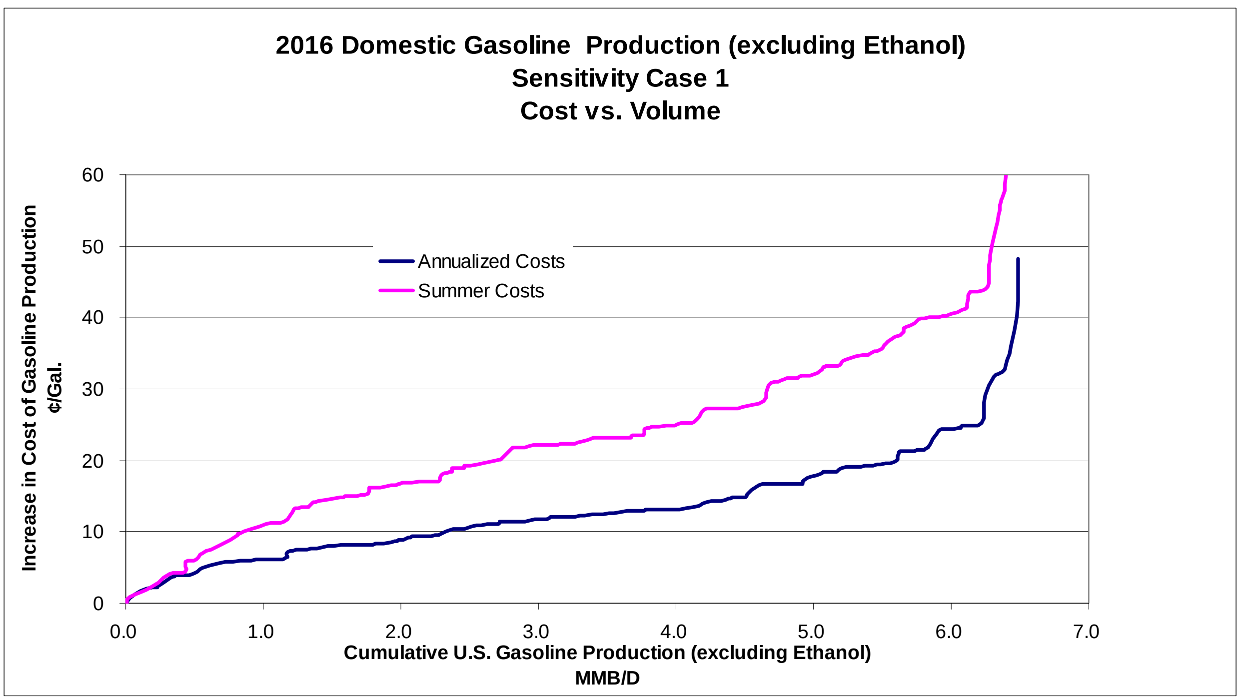
The total annual compliance cost borne by refiners for the Study and Sensitivity Cases is shown below:

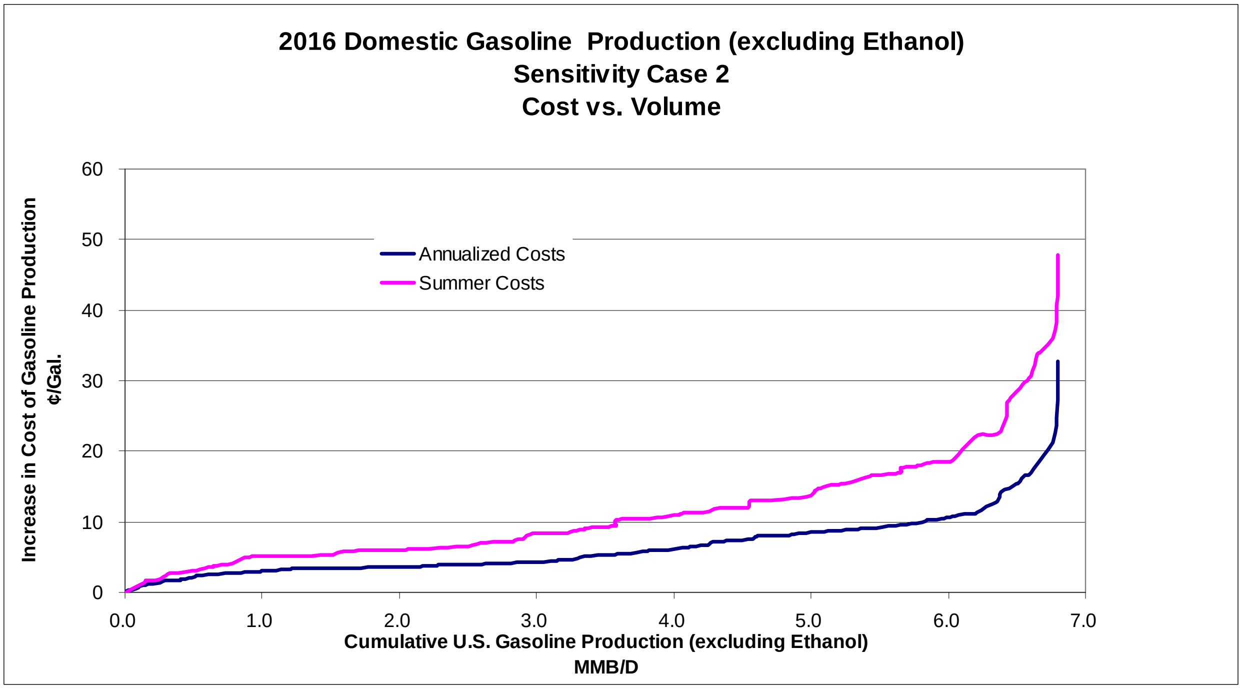
Total Annual Compliance Cost
2009 $MM per Year

	Study Case	**Sensitivity Case 1**	**Sensitivity Case 2**	**Sensitivity Case 3**
Purchased Hydrogen	305	546	354	354
Other Variable Operating Expenses	498	749	342	303
Fixed Operating Expenses	269	404	37	35
Capital Recovery	1,953	2,949	1,693	1,628
Light Hydrocarbon Downgrading	7,368	8,572	4,363	2,528
Total Cost	10,393	13,220	6,789	4,848

The annualized and summer compliance costs for individual refineries are shown for the Study and Sensitivity Cases in graphs that follow.






2016 Domestic Gasoline Production (excluding Ethanol)
Sensitivity Case 2
Cost vs. Volume
Annualized Costs
Summer Costs
Increase in Cost of Gasoline Production
¢/Gal.
Cumulative U.S. Gasoline Production (excluding Ethanol)
MMB/D
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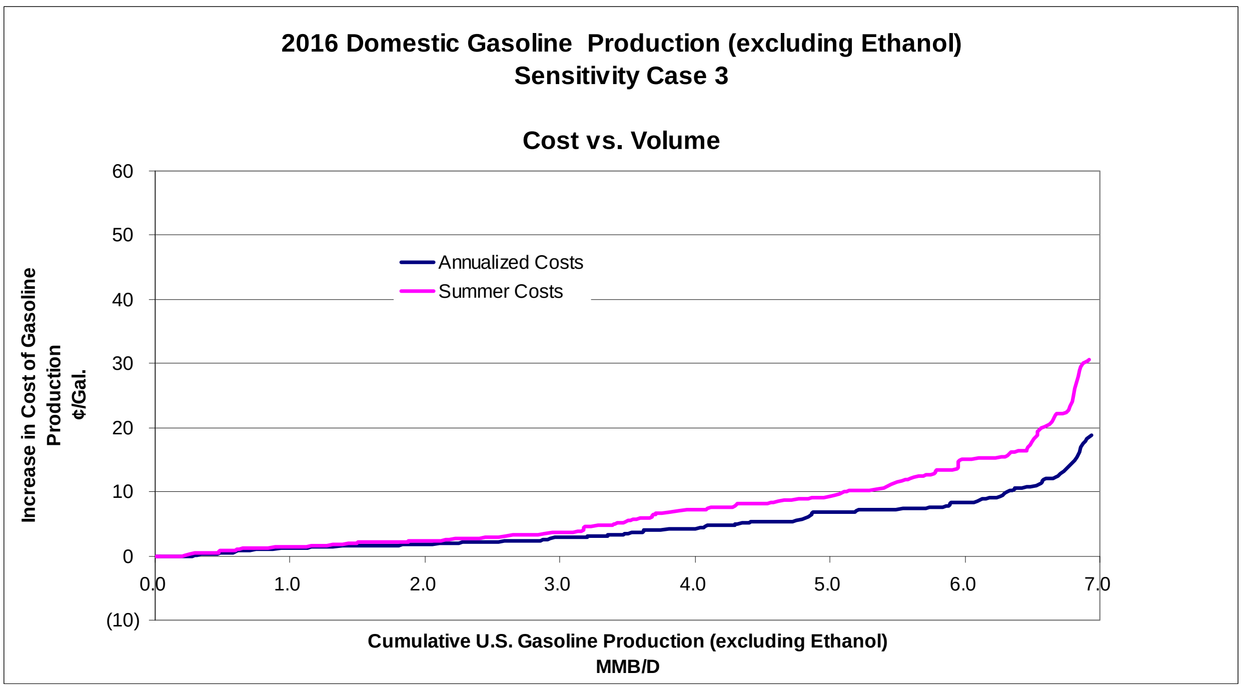
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¢/Gal.
Cumulative U.S. Gasoline Production (excluding Ethanol)
MMB/D
(10)
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10
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7.0

IV. REGULATORY ASSUMPTIONS

Historically, ASTM International (formerly known as the American Society for Testing and Materials) has published standards for minimum gasoline quality that varied seasonally and geographically. These standards have been adopted by many, but not all, states and have long been the minimum standards for gasoline sold in the U.S. Over the last several decades, the U.S. federal government has imposed a number of additional and more stringent gasoline quality requirements in an effort to reduce emissions from the combustion of gasoline and improve air quality. These standards vary seasonally and geographically. Additionally, the federal government has required individual states to develop State Implementation Plans (SIPs) to meet federal air quality standards. Several of the SIPs have imposed additional gasoline quality standards that create unique gasoline specification requirements for small geographical regions.

In June 2009, the Alliance of Automobile Manufacturers published a report (the AAM Report) documenting purported costs and benefits of a single national standard for gasoline quality that would apply to all states except California. The AAM Report calls the new gasoline standard "National Clean Gasoline" or NCG. The proposed NCG standard has some elements that would impact refinery operations all year long (i.e., the reduced sulfur specification) and some that would only impact summer blending (i.e., the reduced Reid vapor pressure [RVP] specification). This report examines four possible regulatory scenarios for gasoline with lower sulfur and lower RVP: a Study Case and three Sensitivity Cases.

The Base Case for the analysis assumes that the existing Tier-2 gasoline sulfur (maximum annual average of 30 parts per million [ppm]) and Mobile Source Air Toxics ([MSAT2] maximum annual average of 0.62 volume percent [Vol.%] benzene in gasoline) are fully implemented. The impacts of potential changes in fuel specifications that could result from "proposed" regulations, such as more stringent ground level ozone standards or NAAQS requirements, were not analyzed in any of the Cases.

Most of the analysis described in this report was completed before the Environmental Protection Agency (EPA) approval of a gasoline formulation with 15% ethanol for late-model automobiles. Because of the uncertainty in what specifications for motor gasoline containing more than 10% ethanol might be, it was assumed that the 10% limit would remain in place on all motor gasoline other than E85.[13] The analysis is, therefore, focused on the impact of the potential lower sulfur and lower RVP specifications, and complications related to changes in ethanol content are avoided.

In the Study Case and Sensitivity Cases 2 and 3, it was assumed that each refining company would be required to meet an average annual sulfur limit of 10 ppm, with a maximum cap of 20 ppm on individual gasoline batches by 2016. In Sensitivity Case 1, the company average limit is set at 5 ppm, and the cap is set at 10 ppm. To ensure compliance, it was assumed that companies would actually produce gasoline with sulfur levels slightly below the standard. In the Study Case and Sensitivity Cases 2 and 3, company average sulfur was limited to 9 ppm, and the individual batch limit was set at 18 ppm. In Sensitivity Case 1, these were limited to 4.5 and 9 ppm, respectively. No inter-company trading of sulfur credits was assumed.

In all Cases a summer (April to September) 7 pounds per square inch absolute (psia) maximum RVP specification was assumed in all Reformulated Gasoline (RFG) Areas,[14] and in Conventional Gasoline (CG) area that currently require this RVP during the summer. It was assumed this RVP standard would replace the existing EPA complex model volatile organic compounds limits. In the Study Case and Sensitivity Case 1, it was assumed that the 7 psia summer limit would also apply in all other regions, except California. In Sensitivity Case 2, a 7.8 psia limit was assumed in these

[13] E85 refers to a gasoline-ethanol blend containing a nominal 85% ethanol by volume.
[14] Including the Chicago-Milwaukee region.

other regions. In Sensitivity Case 3, the RVP limit in these regions was set at 7.8 psia, plus a 1 psia “waiver” for ethanol blending.

For the remainder of the year, it was assumed that the existing regional and seasonal RVP specifications would remain in effect. All other gasoline specifications were assumed to be the same as in the Base Case. A comparison of the key gasoline specifications considered in this report and those proposed in the AAM Report is shown in the table below.

Regulatory Assumptions

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**RVP limited to 7.0 psia in current RFG areas and other areas currently requiring 7.0 psia. RVP limited to 7.8 psia in all other regions except California.

*** No units apply, but in this context, temperatures are measured in degrees Fahrenheit (°F).

The above specifications were assumed to apply in all states except California, where existing California Air Resource Board (CARB) specifications were assumed to remain unchanged.

GREENHOUSE GAS EMISSIONS

Carbon dioxide (CO_2) emissions from refineries were calculated for all cases, but no cost was assigned to these emissions. Because a cost has not been assigned to CO_2 emissions, there is a possibility that refineries that have been assumed to be operating in this analysis could be shut down as a result of regulations to control and reduce CO_2 emissions. These potential shutdowns could significantly change the results shown in this report.

OTHER REGULATIONS

In addition to the gasoline specification changes, impacts of the following existing fuel-quality regulations were included in the all cases:

- Ultra Low Sulfur Diesel (15 ppm maximum at retail location);
- Marine diesel limited to 0.1 weight percent sulfur; and
- All No. 2 heating oil is limited to 500 ppm sulfur.

V. GASOLINE CONSUMPTION FORECAST

In December 2009, the Energy Information Administration (EIA) published an early release of its Annual Energy Outlook 2010 (AEO 2010). In this study, 2016 U.S. consumption of petroleum products is assumed to be constant in all cases and consistent with the AEO 2010 Reference Case[15], and is reported on a Petroleum Administration Defense District (PADD) basis. Because AEO 2010 projections are presented on a different regional basis, the AEO 2010 regional forecasts have been disaggregated and then re-aggregated on a PADD basis.[16] The 2016 consumption forecast was further divided between the summer and winter sub-cases on the basis of seasonal consumption in 2005 to 2006. The 2005 to 2006 time frame was selected, because it represents a more normal consumption pattern, unaffected by the volatile economic conditions in 2008 and 2009.

The AEO 2010 Reference Case includes separate line items for "motor gasoline" and "E85". Each of these categories includes both ethanol and petroleum-sourced gasoline; motor gasoline is assumed to be E10.[17] Because of the uncertainty associated with potential specifications for motor gasoline containing more than 10% ethanol and to keep this study focused on its primary purpose, it was assumed that all motor gasoline would be E10 in the analysis period.

The 2016 gasoline consumption forecast and a comparison to 2005 to 2006 are shown in Table 1. (Numbered tables are located at the end of this report.)

[15] Subsequent to the completion of our analysis, the EIA published an early release of the AEO 2011. The 2016 gasoline consumption forecast in the AEO 2011 early release is 1.2% above the forecast used in this report. The revision does not significantly impact the conclusions of this report.

[16] The AEO 2010 forecast of motor gasoline and E85 consumption was allocated to individual states based on vehicle miles traveled in 2005-2006, as reported by the U.S. Department of Transportation. Consumption of other products was allocated to individual states based on average annual consumption patterns in 2005-2006, as published by the EIA in *Petroleum Marketing Monthly*.

[17] E10 refers to a gasoline-ethanol blend containing a nominal 10% ethanol by volume.

VI. TECHNOLOGY AND CAPITAL INVESTMENT COSTS

All costs in this report are expressed in constant 2009 U.S. dollars.

FRACTIONATION

The summer RVP limits in the Study and Sensitivity Cases would require additional removal of low boiling point, high-RVP blendstocks from the gasoline pool at many refineries. Butanes would likely be the first to be rejected, followed by pentanes and pentenes contained in the light straight run, light hydrocrackate, and the light FCC gasoline. It is expected that new depentanizers would be required at many refineries.

The removal of butanes and pentanes from the gasoline blend pool raises the DI of the remaining pool. Therefore, refineries that must install depentanizers to meet the summertime RVP limit would also need to reduce naphtha and/or fluid catalytic cracker (FCC) gasoline endpoints to meet summer DI specifications. In some cases, the butanes and pentanes/pentenes removed from the gasoline pool have lower sulfur content than the remainder of the pool. Removing butane and pentanes/pentenes from the pool would tend to complicate the task of meeting gasoline sulfur limits in these refineries.

FCC FEED AND GASOLINE DESULFURIZATION

Tier 2 gasoline regulations took effect in 2004 and required almost all refiners to lower their annual average gasoline pool sulfur to a maximum of 30 ppm by December 31, 2009. FCC gasoline is the primary source of sulfur in the gasoline pools in most U.S. refineries. As a result, most refiners responded to Tier 2 requirements by reducing FCC gasoline sulfur though FCC feed hydrodesulfurization, FCC gasoline desulfurization, or a combination of the two. Further reduction in finished gasoline sulfur would require revamps and expansions of existing FCC feed and gasoline desulfurization units and/or construction of new units.

In this report, a revamp is defined as the addition of catalyst volume to lower the space velocity and increase desulfurization without adding additional feed capacity. Revamps may require additional reactor vessels or significant modifications to reactor vessels and possibly compressors, but modifications to the remainder of the unit are not required. An expansion is an increase in unit capacity which likely would include additional reactor/catalyst volume and also modifications to the feed preheat and product fractionation sections.

To meet Tier 2 sulfur limits, some refiners installed FCC gasoline fractionators in combination with heavy FCC gasoline hydrotreaters, but did not install reactors to hydrotreat light FCC gasoline. Many of these refiners would need to hydrotreat light FCC gasoline to meet the Study and Sensitivity Cases' sulfur requirements. The addition of a light FCC gasoline hydrotreater reactor has been treated as an expansion rather than a revamp in this analysis.

CAPITAL COSTS FOR GRASSROOTS UNITS

Inside the battery limits (ISBL) capital costs for the technologies used in this study were estimated using the formula:

$$\text{ISBL Cost} = \text{Base Cost} * (\text{Actual Capacity}/\text{Base Capacity})^{SF}$$

where:

- Base Capacity refers to the capacity of a unit for which there is an estimated construction cost;
- Base Cost refers to the estimated construction cost for that unit;
- Actual Capacity refers to the capacity of a unit for which a cost estimate is required, and would vary by refinery; and
- SF = Scale Factor (typically 0.6 to 0.7).

The following table shows the base cost, base capacity, and SF coefficients for each technology.

Process Unit Inside Battery Limits Capital Cost Assumptions
Second Quarter 2009

	FCC Gasoline Hydrodesulfurization[1]	FCC Feed Hydrodesulfurization[2]	Dependanizer[3]
Capacity (B/D)	35,000	35,000	20,000
Capital cost (million $)	228.8	163.6	7.0
Scale Factor	0.67	0.67	0.39
Initial Catalyst & Chemical $/MB/D)	0.08	0.08	

1. Based on reported total installation costs of several units since 2001 minus assumed 20% outside battery limits (OSBL) costs and inflation based on discussions with refiners.
2. Assumed an ISBL cost between the reported total installed cost of ULSD units and mild hydrocracker units minus assumed 20% OSBL costs.
3. Baker & O'Brien estimate.

REVAMP/EXPANSION COSTS

For revamps as defined above, it was assumed the investment cost would be 30% to 70% of the ISBL replacement cost of a grassroots unit, depending on the extent of the revamp. For expansions, the investment cost was assumed to be 150% of the difference in ISBL replacement cost between the Base Case and the alternate Case.

NATURAL GAS LIQUID (NGL) STORAGE AND LOADING COSTS

New or expanded loading and unloading facilities (storage tanks, piping, vapor recovery systems, pumps, rail car loading spots, etc.) would be required at refineries to handle the volume of NGLs that would be sold if the summer gasoline RVP specification is lowered to 7 psia nationwide. The scope of such modifications would vary by refinery and depend on a refiner's existing loading/unloading infrastructure and capability. A capital investment cost of $140 per barrel (Bbl.) of storage capacity[18] on a U.S. Gulf Coast (USGC) basis was assumed, and it was further assumed that refiners would install storage capacity equal to 10 days of production.

OTHER OFF-SITE CAPITAL COSTS

It was assumed that no additional investment for off-sites would be required unless new units or new equipment were installed (i.e., a depentanizer). Process off-site investment costs were estimated at 20% of the ISBL cost. Non-process off-sites costs were estimated at 15% of the ISBL, and spare parts and catalyst at 1.2% of the ISBL cost.

CONTINGENCY ALLOWANCE

Because of the considerable uncertainty associated with actual capital costs, it is prudent to apply some reasonable "contingency" allowance to capture unidentified costs that can be expected during construction. A contingency allowance of 20% of the combined ISBL and outside battery limits costs was assumed.

CAPITAL INVESTMENT CHARGE

Estimated capital costs were converted into a unit charge based on the barrels of product produced and an assumed return on total investment. Refiners would not normally invest in a project unless they anticipate a rate of return commensurate with the opportunity cost of capital. It was assumed that refiners would require a 10% after-tax rate of return based on a 15-year operating life, a ten-year accelerated depreciation schedule, a 38% tax rate, and a two-year construction period.

[18] Based on applying a cost representing the midpoint of the range recommended for butane storage in the 5th edition (2007) of “Petroleum Refining: Technology and Economics,” by James H. Gary, Glenn E. Handwerk, Mark J. Kaiser, and escalated to 2009 dollars by using the Nelson Farrar Refinery Construction Cost Index.

VII. INPUT COSTS

NATURAL GAS COST

The most significant operating cost was natural gas. Natural gas costs used in this study are above current levels, but within 10% of those reflected in both the New York Mercantile Exchange annual average futures values and the AEO 2010 for 2011 and 2012.

HYDROGEN COSTS

If individual refineries were unable to meet increased hydrogen requirements associated with additional gasoline desulfurization, it was assumed incremental hydrogen requirements would be supplied by outside sources. The cost of natural gas usually comprises approximately half the total cost (including capital charges) of manufacturing or purchasing hydrogen from outside sources. The cost of purchased hydrogen was assumed to be 2.38 times the cost of natural gas on an energy-equivalent basis. Such a value has historically been adequate to encourage third-party companies to build hydrogen production capacity using steam methane reforming technology and supply hydrogen to refiners under term-sales contracts.

In some situations, refiners may find lower-cost sources for small increases in hydrogen production by making changes to reformer operations, from expansion of existing hydrogen plants, and through recovery of hydrogen from refinery fuel systems. These sources are expected to be limited and are not included in this study.

VIII. ANALYTICAL BASIS

Even without new gasoline sulfur and RVP rules, compliance with existing regulation is placing difficult and expensive burdens on the refining industry. Numerous federal and state regulations are adding to the cost of merely staying in business. State and federal emissions standards at refineries in non-attainment areas necessitate the expenditure of capital on new emissions control equipment. Revisions to new source review standards are currently being challenged in court. Depending upon the outcome, there could be an increase in the cost of investments needed to comply with fuel quality regulations.

Each refinery is unique given its current technology, location, product slate, etc. Therefore, a refinery-by-refinery analysis was performed that considered each refinery's compliance options accounting for technical, strategic, market, and economic factors, and then predicted a likely response based on this information. It is believed this approach is superior to aggregate or notional-type modeling, given the likely variation in refinery response to regulation, based on each refinery's unique position.

REFINERY MODELING

The *PRISM* Refining Industry Analysis modeling system was used extensively throughout this study. The *PRISM* system includes a sophisticated, mass-balanced refinery simulator that is based on non-linear yield correlations for conversion units and optimized blending of gasolines and distillate fuels. Variable operating costs are calculated on a process unit by process unit basis, and detailed estimates of fixed operating costs are made based on the refinery capacity and configuration. The complete *PRISM* system includes models of virtually every refinery in North America, along with a crude assay library (containing over 210 different crude oils), product distribution channels, market prices for products, and pipeline tariffs. It includes fixed and variable operating cost and capital replacement cost estimates for each refinery, and provides a systematic method of evaluating and comparing refinery operating and financial performance over time and across different markets. The *PRISM* system was used to model the operations of individual U.S. refineries for each of the Cases.

REFINERY CAPACITY AND UTILIZATION

Baker & O'Brien routinely makes an independent assessment of process unit capacity for individual refineries based on publicly-available information, including the EIA annual survey of refinery capacity and other sources. Refining capacity is usually reported on either a calendar day (CD) or a stream day (SD) basis. We define SD capacity as the maximum rate at which a unit can produce or consume material during a continuous 24-hour period.

CD capacity represents the maximum sustainable capacity to produce or consume material over an extended period of operation and accounts for the capacity that is lost during planned and unplanned outages. CD capacities are typically around 90% of SD capacities. All the capacities used in this report are CD capacities, and by definition it is possible for individual process units to sustain operations at 100% of these capacities. CD capacity utilization of 100% is typically equivalent to 90% utilization of SD capacity.

The Base Case refinery capacity estimate began with our estimates of 2009 capacities. Announced refinery projects that are expected to be completed before 2016 include:

- BP – Whiting Expansion;
- Holly – Tulsa Refineries Integration;
- Marathon – Garyville Expansion;
- Motiva – Port Arthur Expansion;
- Total – Port Arthur Coker; and
- WRB Refining – Wood River Coker Expansion.

It was also assumed that the capacity associated with announced permanent refinery closures would not be available in 2016. These closures include:

- Sunoco – Eagle Point;
- Western – Bloomfield; and
- Valero – Delaware City.[19]

Modifications required to comply with existing regulations listed in Section IV of this report were assumed to be completed before 2016. No other refinery investments, capacity "creep," or shutdowns are included in the 2016 Base Case. Current and 2016 Base Case refining capacities are shown in Table 2. The AEO 2010 Reference Case figures are provided for comparison.

Refinery utilization rates in the Base Case were calibrated to match the AEO 2010 Reference Case crude throughputs and utilization rates as closely as possible.

CRUDE SLATE

Except at those refineries with announced projects that impact their crude slates, it was assumed that refineries would continue running crude slates comparable to those currently being run. It is recognized that domestic crude production is declining, and it was assumed that foreign crudes with equivalent qualities would be purchased to replace the declining domestic crudes. Crude slates are the same in the Base, Study, and Sensitivity Cases.

SEASONALITY

To adequately evaluate the impact of the Study and Sensitivity Cases' summer RVP reduction, it was necessary to run the individual refinery models in both a summer and winter mode. This made it possible to address the full magnitude of NGLs disposition and management issues in the summer.

[19] Subsequent to the completion of the initial modeling work, the Delaware City refinery was purchased by a subsidiary of PBF Energy Company LLC, which announced its intention to restart the refinery.

CALIFORNIA REFINERIES

Although the specifications for California gasoline do not change in the Study and Sensitivity Cases, there are several California refineries that produce non-California gasoline. These refineries were included in the analysis.

DISPOSITION OF EXCESS NGLS

Imposition of the Study or Sensitivity Cases' summer RVP specifications would cause large quantities of NGLs to be removed from gasoline and to be sold as NGLs by refiners. This would likely cause some combination of the following:

- A reduction in butane and/or pentane imports;
- Substitution of butane and/or pentane for other ethylene cracker feedstocks;
- An increase in butane and/or pentane exports to foreign markets;
- Consumption or sales of butane and/or pentane as fuel or as feedstock for hydrogen production;
- Alkylation of FCC Pentanes,[20] and;
- Increased seasonal stockpiling of NGLs.

REDUCE NGL IMPORTS

The U.S. imported an average of 42 thousand barrels per calendar day (MB/CD) of n-butane, 26 MB/CD of Pentanes Plus, and roughly 100 MB/CD of petrochemical feedstock naphtha during 2006 through 2008. It would be expected that any scenario which resulted in a large surplus of refinery produced NGLs would trigger a significant curtailment or elimination of these imports.

DISPLACE OTHER ETHYLENE CRACKER FEEDSTOCKS

The U.S. ethylene industry has the capability to consume nearly 2 million barrels per calendar day (MMB/CD) of combined ethane, propane, butane, and other petroleum

[20] FCC Pentanes refers to the mix of 5-carbon molecules produced from an FCC unit and includes C5 olefins and di-olefins.

liquids.[21] Feedstock consumption for U.S. ethylene producers during the 2000 through 2008 period was within the ranges below:[22]

Feedstock Consumption in U.S. Ethylene Plants	Consumption Range 2000-2008, MB/CD	Consumption Midpoint MB/CD
Ethane	400 - 800	650
Propane	200 - 450	350
Butane	0 - 140	50
Light and Heavy Liquids	400 - 750	550
Total		**1,600**

The relative portion of feedstock consumed by ethylene crackers varies dynamically, as most producers optimize their feedstock slates based on real-time feedstock and product prices. Not all ethylene crackers have the flexibility to consume all types of feedstock. Approximately 50% of U.S. ethylene is produced from crackers, which have the flexibility to consume either NGLs or liquid feedstocks.[23]

If the surplus refinery-produced NGLs are substituted for other ethylene cracker feedstocks, the displaced ethylene feedstocks would need to be accommodated elsewhere. While there are options available for balancing the supply of these feedstocks, these options are somewhat limited.

- Ethane has no market outlet other than as ethylene feedstock. If ethane is displaced from ethylene crackers, the only option for balancing ethane supply is to reduce the quantity of ethane extracted from natural gas to the extent permitted by common carrier natural gas pipeline specifications.
- Displacing propane and heavier NGLs would likely cause a reduction in U.S. waterborne imports. The U.S. imported an average of 165 MB/CD of propane and 150 MB/CD of "heavy liquids" (greater than 400°F end point) during 2006

[21] Baker & O'Brien analysis based on information provided in the *Oil & Gas Journal* "Special Report - International Survey of Ethylene From Steam Crackers – 2009," July 27, 2009.
[22] U.S. Ethane Outlook – Conclusion: "Midstream, petchem players must face problems of increased ethane capacity," *Oil & Gas Journal*, February 23, 2009.
[23] Ibid.

through 2008. While propane competes with heating oil in the home heating market, it is unlikely that fuel switching would become a major factor in balancing propane supply.

It is important to note that changes in ethylene cracker feed composition would result in changes in product mix. For instance, if U.S. crackers substitute butanes for naphtha, these crackers would produce much lower quantities of aromatics. If they substitute butanes for ethane, they would produce higher quantities of propylene and C4 co-products. The change in product mix would have repercussions throughout the U.S. petrochemicals supply chain. A detailed analysis of ethylene cracker feedstocks is beyond the scope of this study.

EXPORT MARKETS

The U.S. exported a relatively small quantity of n-butane during 2006 through 2008, averaging 14 MB/CD. Over the past 20 years, the U.S. has demonstrated peak n-butane export volumes of roughly 45 MB/CD. Therefore, the U.S. has the capability to export at least an additional 30 MB/CD of n-butane above the 2006 to 2008 average. Export capacity could be significantly higher since Enterprise Products Partners reportedly has the capability to export over 100 MB/CD of propane and butane.[24]

U.S. exports of Pentanes Plus have increased from 12 MB/CD in 2006 to 39 MB/CD in 2009. These exports were all destined for Canada for use as a diluent to facilitate the pipeline transport of heavy Canadian crude oil and bitumen. While increases in Pentanes Plus exports may continue, this increase would likely be a simple recycling of diluent imported from Canada; diluent is probably not a significant new market for Pentanes Plus produced in the U.S. from other sources.

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[24] Enterprise Products Partners reported in their 2009 Form 10K Filing (p.12) that they can load refrigerated propane and butane onto tanker vessels at rates up to 6,700 barrels per hour.

CONSUME OR SELL AS FUEL OR HYDROGEN FEEDSTOCK

Some refiners may elect to modify their hydrogen plants to consume butanes and/or pentanes, while others may elect to consume these materials as fuel in their steam boilers, furnaces, or nearby combined heat and power plants.

ALKYLATION

FCC Pentanes can be alkylated with isobutane to yield a low RVP gasoline blendstock. This would not only consume the FCC Pentanes, it would also allow additional pentanes and butanes to be blended into gasoline and partially mitigate lost gasoline production. Traditionally, economics have not favored the alkylation of FCC Pentanes, partially because the octane ratings of the resulting alkylate are lower than those produced with other feedstocks and because acid catalyst consumption and resulting operating costs are significantly higher than for other feedstock.

Alkylation of FCC Pentanes, as a partial solution to the problem of excess refinery NGLs generated by the Study and Sensitivity Cases RVP limits, would require capital investments in alkylation capacity. The Study and Sensitivity Cases assume that refiners only make investments required for compliance. Since investment in additional alkylation capacity is not required for compliance, they were not included in the analysis.

The potential that some refiners might make these investments certainly exists. Refiners would make these incremental investments if they anticipated earning an adequate return on the investment. This was accounted for in the valuation of excess refinery NGLs.

STOCKPILE FOR WINTER CONSUMPTION

The U.S. stockpiled just over 360 MB/CD of NGLs during the summer months of 2006 through 2008 for consumption during the winter months.[25] Summer stockpiling of propane and n-butane for winter consumption is commonplace in the U.S. These

[25] Based on an analysis of statistics reported by the EIA through the Petroleum Navigator located at http://tonto.eia.doe.gov.

products are stockpiled in underground salt dome caverns, primarily in the USGC. The seasonal stockpiling of Pentanes Plus is an option that would be considered by participants in the refining, chemical, and NGLs industries to respond to a summer surplus of Pentanes Plus.

NGLS TRANSPORTATION

The vast majority of refinery Pentanes Plus is blended into gasoline, so there is very limited logistics infrastructure dedicated to Pentanes Plus transportation. Mont Belvieu, Texas, is a major clearing hub for U.S. NGLs, and could be the primary destination for surplus NGLs produced by refineries in the Study and Sensitivity Cases. Mont Belvieu is connected by an extensive pipeline network to a large number of refineries and petrochemical facilities, as well as to the largest U.S. NGL import/export facility. Those refineries that are either connected to Mont Belvieu by two-way pipelines, or are located adjacent to flexible feed ethylene crackers, would not be expected to require any significant infrastructure modifications to enable the disposition of surplus NGLs. Some refiners, particularly those on the Houston Ship Channel, may be able to utilize pressurized barges to transport surplus NGLs. However, refineries located outside of USGC would most likely need to transport their surplus NGLs by rail car to the USGC.

Rail transport of NGLs requires special-purpose rail cars, referred to as high-pressure tank cars. It is estimated that high-pressure tank cars represent approximately 3% of the 1.75MM U.S. rail car fleet.[26] These cars typically transport NGLs and a number of chemical products. High-pressure tank cars typically hold about 30,000 gallons of product.

The number of rail cars that would be required to transport surplus refinery produced NGLs was calculated by dividing the aggregate daily surplus for each PADD

[26] Baker & O'Brien estimate.

that would be transported to the USGC by the average rail car size (30,000 gallons) and then multiplying by the round-trip transit time between the respective PADD and the USGC.

VALUATION OF EXCESS NGLS

The quantity of NGLs removed from gasoline during the summer in the Study and Sensitivity Cases is very large and would impact the domestic and international markets for NGLs. This would have a significant impact on the value that refiners receive for these products. For the most part, these are relatively clean burning gasoline components with higher than average hydrogen to carbon atomic ratios (i.e., iso-pentane produces less CO_2 per British thermal unit when burned than iso-octane).

Because the incremental or lowest value market for the excess NGLs would be as a substitute for natural gas, a portion of the displaced NGLs would have to compete directly with natural gas. Refiners selling these hydrocarbons into that market would realize a value equivalent to natural gas. Using a pricing scenario consistent with AEO 2010, this value is significantly less than the NGLs' value as gasoline blendstocks. This reduction in value has been treated as a cost to refiners.

Some portion of the displaced NGLs is likely to achieve values greater than natural gas equivalence, but the fact that the incremental value is natural gas equivalence would tend to drive values lower in alternative markets as well. A detailed analysis of the markets for these NGLs was beyond the scope of this study and would not have a significant impact on the results or conclusions. It has been assumed that refiners would realize natural gas equivalent values for volumes used as fuel or sold into export markets. All other light hydrocarbon sales have been valued at the mid-point of their Base Case gasoline blending value and natural gas equivalence.

COMPLIANCE RESPONSE

Faced with the regulations in any of the study scenarios, refiners would have three options:

1) Make the necessary investments to facilitate compliance,
2) Stop making gasoline, or
3) Shut down.

A stepwise approach was taken in analyzing compliance responses. The first step was to determine the minimum capital necessary to comply with the new gasoline standards at each individual refinery. Since summer compliance with both sulfur and RVP reductions would be more difficult than winter, investment decisions would be based on meeting the summer specifications. Any capital improvements installed to meet the summer requirements would obviously be in place in the winter, regardless as to whether they are needed in the winter.

Each refinery was reviewed using the following procedure:

1. Debutanizers and depentanizers were added to the extent needed to meet the 7 psi RVP specification.
2. If debutanization or depentanization caused problems with the DI specification, then FCC heavy gasoline end points were reduced, but no lower than 360°F.
3. If reducing the FCC heavy gasoline end point was insufficient to meet the existing DI specifications, crude naphtha end points were reduced.
4. If a refinery had an existing FCC feed desulfurization unit and no FCC gasoline hydrotreater, the existing unit was revamped to the extent possible to meet the lower gasoline sulfur limit.
5. Existing FCC gasoline desulfurization units were revamped or expanded as needed to meet the lower gasoline sulfur specification.
6. If expansions and revamps of existing desulfurization units were insufficient to meet the sulfur limits, then new FCC gasoline hydrotreaters were added.

The modified refineries were modeled using the *PRISM* refinery simulator to generate new product yields, expense, and cash margin data. In calculating the new cash margins, crude and product prices were held constant with the Base Case with the exception of the adjustment to light hydrocarbon prices discussed above (i.e., at this point in the analysis, it was assumed that none of the compliance cost would be recovered by refiners).

The new estimated net cash flow for each refinery was reviewed relative to the required investment. If the investment required at any refinery exceeded its “value as an ongoing concern” (assumed to be five times the future annual net cash flow), then it was assumed that the refinery would stop making gasoline. In almost every case, the decision to not make gasoline led to a decision to shut down the refinery.

For the refineries where compliance investments met the value as an ongoing concern, criteria summer variable cash margins[27] were reviewed. If a refinery met the ongoing concern investment test, but was operating with a negative variable cash margin during the summer, it was assumed that the refiner would consider not making gasoline or shutting down entirely during the summer and only make the investments required to comply with the winter gasoline standards.

In practice, each refiner would make investment decisions based on its own forecasts and expectations of compliance cost recovery. After identifying the refineries that might stop making gasoline or shut down completely if they anticipated none of the compliance cost would be recovered, individual refineries were reviewed in the context of their unique situation. Best judgment was applied on a case-by-case basis, and some of these marginal refineries with relatively low compliance costs were assumed to make the necessary compliance investments.

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[27] Variable cash margin is defined as the sum of all product revenue less the cost of feedstocks and only expenses that vary with operating rates. For example, fuel and power consumption will vary with operating rates, but property taxes and insurance do not. Expenses that do not vary with operating rate are defined as fixed costs.

OTHER GASOLINE SUPPLY

The AEO 2010 Reference Case includes 300 MB/CD of "other" supply to the transportation fuels market in 2016. EIA staff[28] indicated that one-third to one-half of this is Non-Esterified Renewable Diesel (NERD). The remainder is other blending components, other hydrocarbons, and renewable feedstocks for the on-site production of diesel and gasoline. In the Base Case it has been assumed that 100 MB/CD NERD and 200 MB/CD of gasoline blending components would be supplied to the domestic market from sources other than domestic refineries and imports. It is reasonable to assume that the reduction in RVP in the Study and Sensitivity Cases would impact the supply of the non-refinery domestic gasoline components to at least the same extent proportionally as refinery produced gasoline, but a detailed analysis was not performed.

IMPORTS

As discussed in Section V of this report, demand side response has not been analyzed for the Study and Sensitivity Cases. Gasoline consumption was held constant in all cases. Imports in the Base Case are consistent with the AEO 2010 Reference Case and history. The availability of imports to meet the requirements of the Study and Sensitivity Cases has not been analyzed.

ETHANOL QUALITY

It was assumed that ethanol has a sulfur content of 10 ppm consistent with the default ethanol properties values specified by California Air Resources Board.[29]

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[28] Conversation with an EIA AEO Forecast Analyst, December 15, 2009.

[29] Procedures for Using the California Model for California Reformulated Gasoline Blendstocks for Oxygenate Blending (CARBOB), August 7, 2008.

IX. STUDY RESULTS

BASE CASE GASOLINE SUPPLY BALANCE AND REFINERY OPERATIONS

Using the *PRISM* refining industry model, adjusted for the capacity changes discussed in Section VIII, 2016 domestic gasoline production for each individual refinery was estimated under Base Case regulations. Supply balances for the Base Case summer, winter, and annual averages are provided in Table 3, Table 4, and Table 5, respectively. On an annual basis, U.S. refiners are projected to produce 7,296 MB/CD of hydrocarbon gasoline,[30] meeting 87% of the domestic requirement. As discussed in Section VIII, non-refinery gasoline production in 2016 is estimated to be 200 MB/CD. Therefore, 885 MB/CD of imported hydrocarbon gasoline would be required to meet the AEO 2010 U.S. consumption forecast for 2016. During the summer, imports of 923 MB/CD are required to balance supply with consumption. Foreign refiners have supplied the U.S. market with this magnitude of gasoline in recent years, but an analysis of the ability to supply the 2016 requirement was not part of this study.

Refinery annual average utilization rates for key process units are provided in Table 6. As mentioned in Section VIII, these utilization rates are based on our estimates of CD capacities. Utilization rates based on SD capacities would be lower. In the Base Case, regional average crude unit utilization rates range from a low of 79% in PADD 5 to a high of 93% in PADD 4. The Base Case U.S. average crude utilization rate of 82% is in line with the AEO 2010 forecast for 2016 of 83%. Average Base Case utilization rates for key process units are within 5% of those observed during the period of October 2008 through September 2009, with the exception of hydrocrackers, which

[30] Changes in gasoline production and imports throughout the report are hydrocarbon only. It was assumed that domestic ethanol production and consumption remain constant at Base Case levels.

are at 91% utilization in the Base Case vs. 80% during October 2008 through September 2009. The higher hydrocracker operating rate is required to achieve a higher production level of light oil products in 2016.

Tables 7A through 7D provide summaries of key gasoline quality results for the summer and winter, with and without ethanol. (As discussed in Section V, all U.S. gasoline is assumed to be either E10 or E85.) Tables 8 and 9 show the domestic production by crude oil refiners for the summer and winter, respectively.

COMPLIANCE RESPONSE

In the Base Case, 112 refineries were producing non-California gasoline (including some California refineries). To meet the lower summer RVP specifications in the Study and Sensitivity Cases additional depentanizers will be required. In the Study Case, a total of 46 refineries will require a total of 108 new depentanizers. In the Sensitivities Cases, the total number of new depentanizers is 103, 38, and 27 respectively. The removal of NGLs from the gasoline blend pool raises the DI of the remaining pool. Many of the refineries must also reduce naphtha and/or FCC gasoline endpoints to meet summer DI specifications.

To meet the Study Case sulfur limits, 30 refineries would need to upgrade existing FCC feed hydrotreaters, one refinery would require installation of a new FCC feed hydrotreater, nine would need to install new FCC gasoline hydrotreaters, and 32 would need to expand or upgrade their existing FCC gasoline hydrotreaters. In Sensitivity Case 1, the required investments are greater.

Applying the methodology and criteria described in the previous section, an estimate of the most likely investment decisions was made for each refinery. That analysis indicated that four refineries would likely shut down rather than make the investments required to comply with the lower sulfur and lower RVP specifications in the Study Case and in Sensitivity Cases 2 and 3. In Sensitivity Case 1, the number of refineries estimated to shut down increases to seven. These refineries are projected to have the potential to make 110 MB/CD of gasoline with lower sulfur and lower RVP in the Study Case, 170 MB/CD in Sensitivity Cases 2 and 3, and 206 MB/CD in Sensitivity Case 1 if they did make the investment. Assuming those refineries do shut down, the expected compliance investments are shown below.

Expected Refinery Compliance Investments

	Study Case	Sensitivity Case 1	Sensitivity Case 2	Sensitivity Case 3
Refinery Shutdowns	4	7	4	4
Number of New Units				
Naphtha Depentanizer	45	43	27	16
FCC Depentanizer	40	38	9	9
Hydrocracker Depentanizer	23	22	2	2
FCC Feed Hydrotreater	1	8	1	1
FCC Gasoline Hydrotreater	9	20	9	9
Number of Revamps and Expansions				
FCC Feed Hydrotreater	30	28	27	27
FCC Gasoline Hydrotreater	32	38	30	30
Logistics/Tankage, $MM	977	1,114	609	366
Total Investment Cost, $MM	11,488	17,343	9,957	9,577

Note: Individual refineries may appear in multiple categories for each case.

STUDY AND SENSITIVITY CASES GASOLINE SUPPLY BALANCE AND REFINERY OPERATIONS

The low summer RVP specification in the Study and Sensitivity Cases results in the removal of a large quantity of domestically-produced hydrocarbon from the gasoline blend pool. In the Study Case, the resulting decrease in summer refinery gasoline production is estimated at 1,157 MB/CD vs. the Base Case. This is equivalent to 14% of projected 2016 summer hydrocarbon gasoline consumption. In Sensitivity Case 1 the loss in production increases to 1,377 MB/CD of domestic summer gasoline supply. In Sensitivity Cases 2 and 3, the reduction vs. the Base Case is 873 and 622 MB/CD, respectively.

Consideration was given to increasing refinery operating rates to offset the decline in gasoline production. An increase in refinery operating rates would increase distillate and NGLs production, requiring additional U.S. exports of these products. The U.S. currently exports diesel fuel and additional exports may be possible. However, even without an increase in crude processing, significant exports of NGLs are required in the Study and Sensitivity Cases, and it is not obvious that foreign markets would accommodate these exports. Therefore, crude utilization rates were held constant at Base Case levels in refineries that continued to operate in the Study and Sensitivity Cases.

In the Base Case, 200 MB/CD of gasoline is provided by non-refining domestic suppliers. As discussed in the previous section, it would be reasonable to assume that the implementation of the Study or Sensitivity RVP limits would impact this supply at least proportionally to the supply lost from refineries.

The net result in both the Study Case and Sensitivity Case 1 and 2 is that summer imports of gasoline (excluding ethanol) would need to more than double vs. the Base Case and almost double in sensitivity Case 3 vs. the Base Case, if projected consumption is to be supplied. At the same time, incremental NGLs removed from U.S.

gasoline would be exported or burned as a substitute for natural gas. The capability of foreign refineries to supply this volume of gasoline with lower sulfur and lower RVP was not studied, but it is questionable. At the very least, the increased dependence on gasoline imports would cause the U.S. to be more vulnerable to supply disruptions.

Because the winter RVP specifications are unchanged from the Base Case, there were no significant changes in refinery production rates compared to the Base Case. The desulfurization facilities required for summer compliance were sufficient to meet the sulfur specification in the winter. Refiners would incur higher winter operating costs vs. the Base Case, primarily because of an increase in hydrogen consumption related to additional FCC feed and FCC gasoline desulfurization.

The details of all modeled scenarios' gasoline quality and supply balances are reported in Tables 10 through 25.

Refinery hydrogen production was reduced in the Study and Sensitivity Cases due to the reduced reformer utilization associated with undercutting naphtha. The combination of the decline in reformer hydrogen production and an increase in consumption for desulfurization results in an annualized increase in net hydrogen purchases of 164 million standard cubic feet per calendar day (MMscf/CD) at refineries operating in the Study Case, and 293, 185, and 185 MMscf/CD at refineries operating in Sensitivity Cases 1, 2, and 3, respectively. These numbers assume that existing refinery hydrogen plants produce at capacity where needed. It was assumed that the incremental hydrogen purchases would be available from third-party steam methane reformers.

Hydrogen Purchases, MMscf/CD

	Total U.S.	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5
Base Case*	1,629.7	20.1	36.5	1326.7	0.8	245.5
Study Case purchases	1,793.6	28.4	64.8	1424.5	1.5	274.5
Delta vs. Base Case**	**163.9**	**8.2**	**28.3**	**97.7**	**0.6**	**29.0**
Delta, %	**10%**	**41%**	**77%**	**7%**	**72%**	**12%**
Base Case*	1,618.4	20.1	36.5	1315.4	0.8	245.5
Sensitivity Case	1,911.2	46.3	93.5	1,469.3	1.5	300.5
Delta vs. Base Case**	**292.8**	**26.2**	**57.0**	**153.9**	**0.6**	**55.0**
Delta, %	**18%**	**130%**	**156%**	**12%**	**74%**	**22%**
Base Case*	1,629.7	20.1	36.5	1,326.7	0.8	245.5
Sensitivity Case 2	1,814.4	28.3	64.5	1,416.6	0.8	304.1
Delta vs. Base Case**	**184.7**	**8.2**	**28.0**	**89.9**	**0.0**	**58.6**
Delta, %	**11%**	**41%**	**77%**	**7%**	**0%**	**24%**
Base Case*	1,629.7	20.1	36.5	1,326.7	0.8	245.5
Sensitivity Case 3	1,814.6	28.3	64.5	1,416.5	0.8	304.4
Delta vs. Base Case**	**184.9**	**8.2**	**28.0**	**89.8**	**0.0**	**58.9**
Delta, %	**11%**	**41%**	**77%**	**7%**	**0%**	**24%**

* The hydrogen purchases are based on the same refineries operating in the Base Case as the Study Case and the Sensitivity Cases, respectively

** Difference in reported delta values are due to rounding.

DISPOSITION OF SURPLUS NGLS

During the summer, the reduction in gasoline RVP would result in 850 MB/CD of NGLs being removed from the domestic gasoline pool in the Study Case and 934, 559, and 315 MB/CD in Sensitivity Cases 1, 2, and 3, respectively. The breakdown of the material rejected during the summer is summarized below:

Change in Summer NGL Supply vs. the Base Case, MB/CD

	Study Case	Sensitivity Case 1	Sensitivity Case 2	Sensitivity Case 3
Additional Refinery Production				
n-butane	73	71	72	57
Pentanes Plus	664	751	374	197
Reduced Refinery Purchases				
n-butane	7	9	7	7
Pentanes Plus	106	103	106	54
Total Surplus	**850**	**934**	**559**	**315**

Because refiners are already running at maximum volatility limits during the winter, there is no room to reabsorb these volumes into the winter gasoline pool. Other outlets would need to be found. The magnitude of these volumes would have a significant impact on the U.S. refining, chemicals, and NGL markets. It is estimated that investments required by refiners to modify their storage, loading, and unloading facilities to store and transport surplus summer NGLs would be nearly $1 billion for the Study Case, $1.1 billion for Sensitivity Case 1, $600 million for Sensitivity Case 2, and $400 million for Sensitivity Case 3. For reasons discussed below, existing transportation and handling infrastructure outside the refinery gate likely cannot accommodate the additional NGLs volume without significant investments. The cost of these outside the battery limits investments has not been estimated as part of this study.

The following table presents a potential scenario for disposing of surplus NGLs:

Potential Disposition of Surplus Refinery Produced NGLs, MB/CD

	Study Case	***Sensitivity Case 1***	***Sensitivity Case 2***	***Sensitivity Case 3***
Reduce imports of NGLs and light naphtha	***160***	***160***	***160***	***80***
Increase exports of NGLs	***150***	***150***	***150***	***140***
Displace ethylene cracker feedstock*	***250***	***250***	***168***	***80***
Stockpile for winter consumption	***75***	***75***	***33***	***15***
Consume as fuel, hydrogen feedstock, or other use.	***215***	***299***	***48***	
TOTAL	***850***	***934***	***559***	***315***

* Excludes the displacement of imported NGLs and light naphtha that are accounted for in the first item above.

This scenario includes the elimination of all waterborne imports of NGLs, plus an increase in NGLs exports to a level exceeding demonstrated maximum export levels. Butane/pentane cracking for ethylene production also exceeds the historic maximum levels outlined in Section VIII of this report. While the level of exports and cracking are above historic maximum rates, these levels could be possible under market conditions which sufficiently depress the cost of butanes and pentanes to ethylene producers.

The 15 - 75 MB/CD of surplus NGLs shown as stockpiled would be consumed during the winter primarily as ethylene cracker feedstock. This would require up to 14 million barrels of underground salt dome storage and associated rail car unloading facilities. It is unlikely that this quantity of storage capacity would already be available, as it represents roughly 20% of the typical seasonal U.S. NGL inventory increase. Therefore, new salt dome storage and associated rail car unloading facilities would likely be required. These facilities would be installed outside of the refinery and would likely be owned and operated by third parties. Their cost is not included this study.

The scenario also includes a substantial quantity of NGLs being consumed in the Study Case and Sensitivity Case 1 as fuel, as feedstock for hydrogen, or other use. The proportion of NGLs consumed in each of these outlets would depend on individual refiner circumstances, economics, and preferences.

While a portion of surplus NGLs in the Study and Sensitivity Cases may be transported by pipeline, the majority would likely be transported to the USGC by rail. It is estimated that an incremental 16,000 high-pressure rail cars would be required to transport NGLs to the USGC, corresponding to roughly 900 rail car loadings per day. The number of rail cars required represents roughly 30% of the U.S. high-pressure rail car fleet,[31] while the number of daily rail car loadings represents approximately 1% of total U.S. rail car loadings.

The U.S. rail car construction industry appears to have the ability to produce 20,000 tank cars per year, with less than 10,000 per year forecasted to be constructed in the near term.[32] However, the lead time for delivery may depend on the backlog at construction facilities.

The disposition of nearly 600 to 1,000 MB/CD of additional NGLs in the Study Case and Sensitivity Cases 1 and 2 would be very challenging, would require new transportation infrastructure, and would impact essentially all major U.S. hydrocarbon processing industries. The 300 MB/CD of additional NGLs in Sensitivity Case 3 would be less challenging, but some investment in storage and transportation infrastructure would still be required. While it may be feasible, sufficient time must be allowed for the design, permitting, and construction of the required facilities, or significant disruptions

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[31] Baker & O'Brien estimate.
[32] Trinity Rail Presentation at NGFA Ag Transportation Symposium, May 12, 2009. Reference to Global Insight May 2009 forecast.

could occur across the refining, petrochemical, NGL, and transportation industries. If refiners are unable to dispose of the projected volumes, it may be difficult to achieve the gasoline production rates shown in the Study and Sensitivity Cases, and the gasoline shortfall would be worse than what is shown.

GREENHOUSE GAS EMISSIONS

The additional hydrotreating and fractionation required in the Study and Sensitivity Cases would result in an increase in CO_2 emission from refineries that continue to operate as shown below.

Incremental CO_2 Emissions
Tonnes/CD

CO_2 Emissions	***TOTAL U.S.***	***PADD 1***	***PADD 2***	***PADD 3***	***PADD 4***	***PADD 5***
Base Case*	717,811	48,248	137,968	375,030	24,241	132,323
Study Case	727,748	48,667	140,932	380,321	24,892	132,935
Delta	**9,936**	**419**	**2,964**	**5,292**	**650**	**612**
Base Case*	708,840	48,248	135,811	368,215	24,241	132,323
Sensitivity Case 1	724,976	49,245	139,793	376,141	25,276	134,521
Delta	**16,136**	**997**	**3,982**	**7,926**	**1,035**	**2,197**
Base Case*	717,811	48,248	137,968	375,030	24,241	132,323
Sensitivity Case 2	725,411	48,502	139,524	379,316	24,583	133,486
Delta	**7,599**	**253**	**1,555**	**4,286**	**342**	**1,163**
Base Case*	717,811	48,248	137,968	375,030	24,241	132,323
Sensitivity Case 3	724,951	48,502	139,429	379,135	24,506	133,379
Delta	**7,140**	**253**	**1,461**	**4,105**	**264**	**1,056**

*The CO_2 values are based on the same refineries operating in the Base Case as the Study Case and the Sensitivity Cases, respectively.

Assuming foreign refineries experience a proportional increase, the combined increase in CO_2 emissions would be 2.9 to 7.4 million tonnes per year. As a result of shifting emissions overseas, incurring additional emissions associated with fuel transport (not included here), and increasing emissions for operating refineries in the U.S., aggregate global CO_2 emissions increase.

TOTAL COMPLIANCE COSTS

The downgrade in NGLs value is by far the largest compliance cost. Capital investment costs are second. Refinery investment costs for the compliance responses discussed above are $11.5 billion in the Study Case and $9.5 to $17.3 billion in the Sensitivity Cases. As mentioned, there are additional investments that would be required outside the refineries that are not included in these totals.

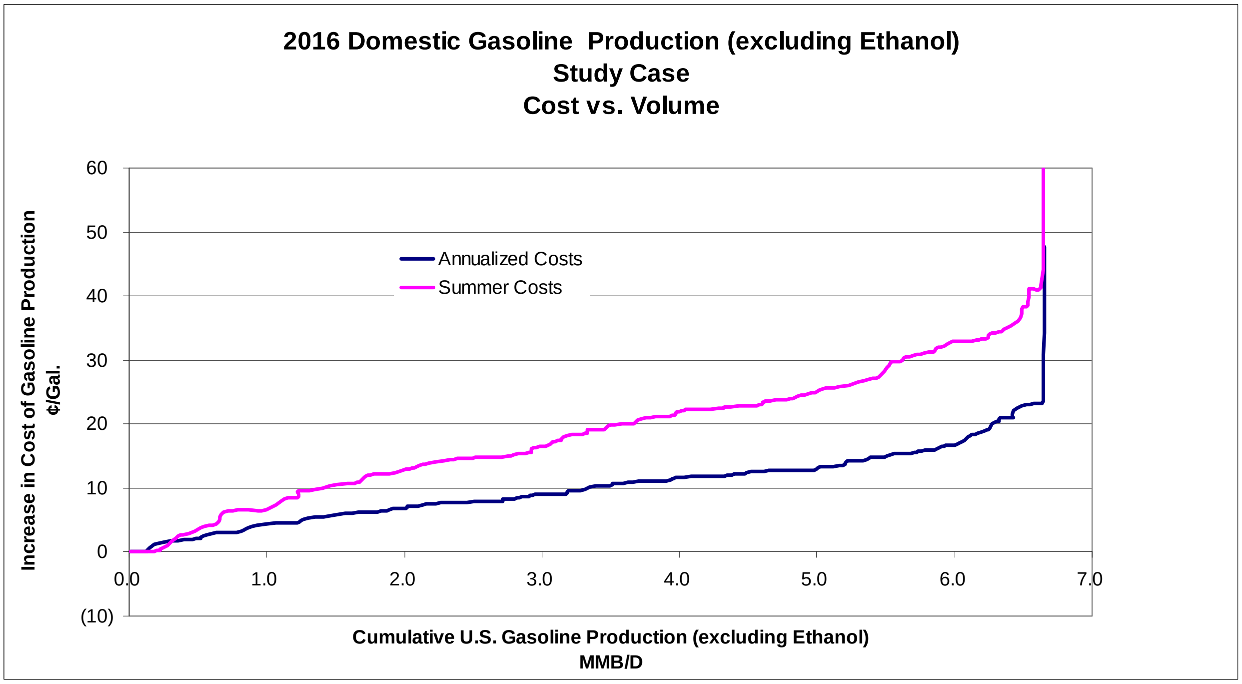
The total compliance costs that would be borne by refiners for the Study and Sensitivity Cases are shown below:

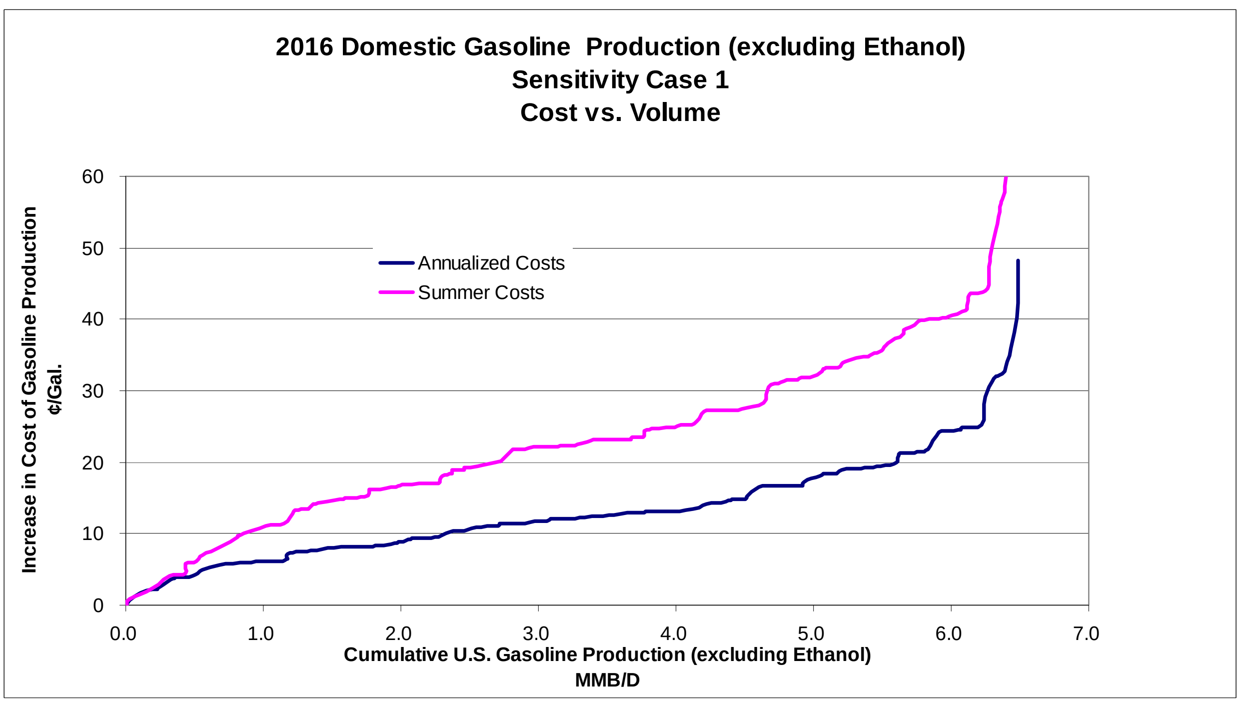
Total Annual Compliance Cost
2009 $MM per Year

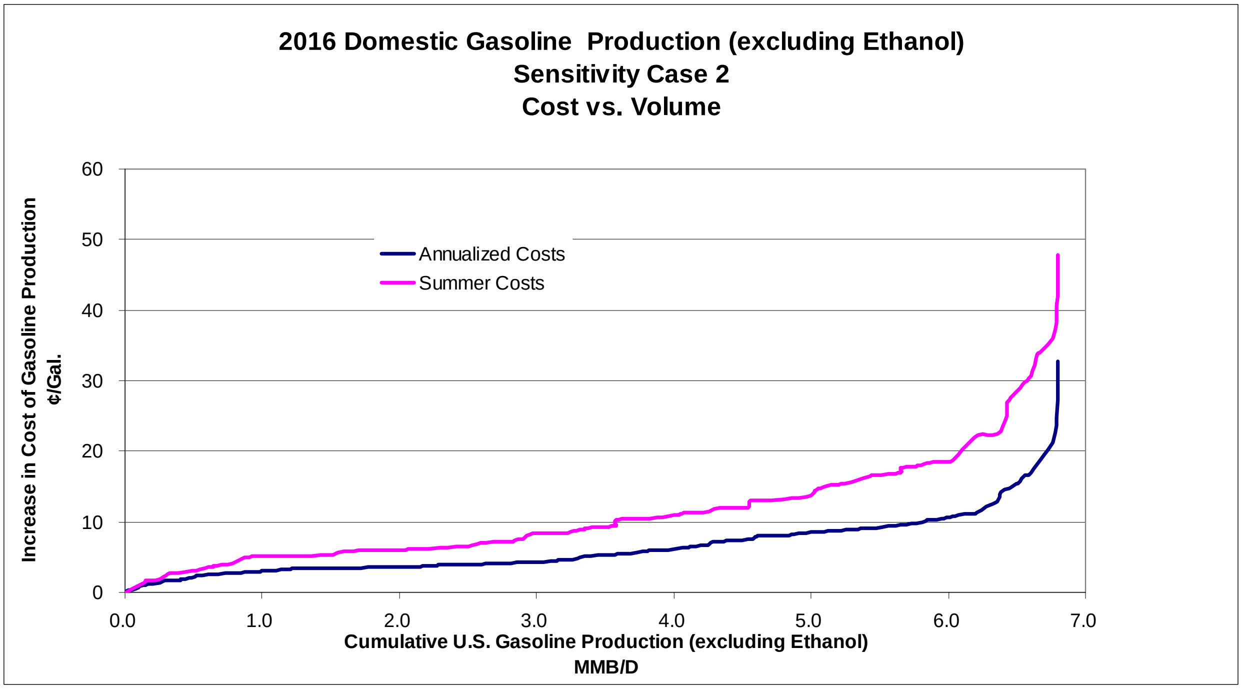
	Study Case	Sensitivity Case 1	Sensitivity Case 2	Sensitivity Case 3
Purchased Hydrogen	305	546	354	354
Other Variable Operating Expenses	498	749	342	303
Fixed Operating Expenses	269	404	37	35
Capital Recovery	1,953	2,949	1,693	1,628
Light Hydrocarbon Downgrading	7,368	8,572	4,363	2,528
Total Cost	10,393	13,220	6,789	4,848

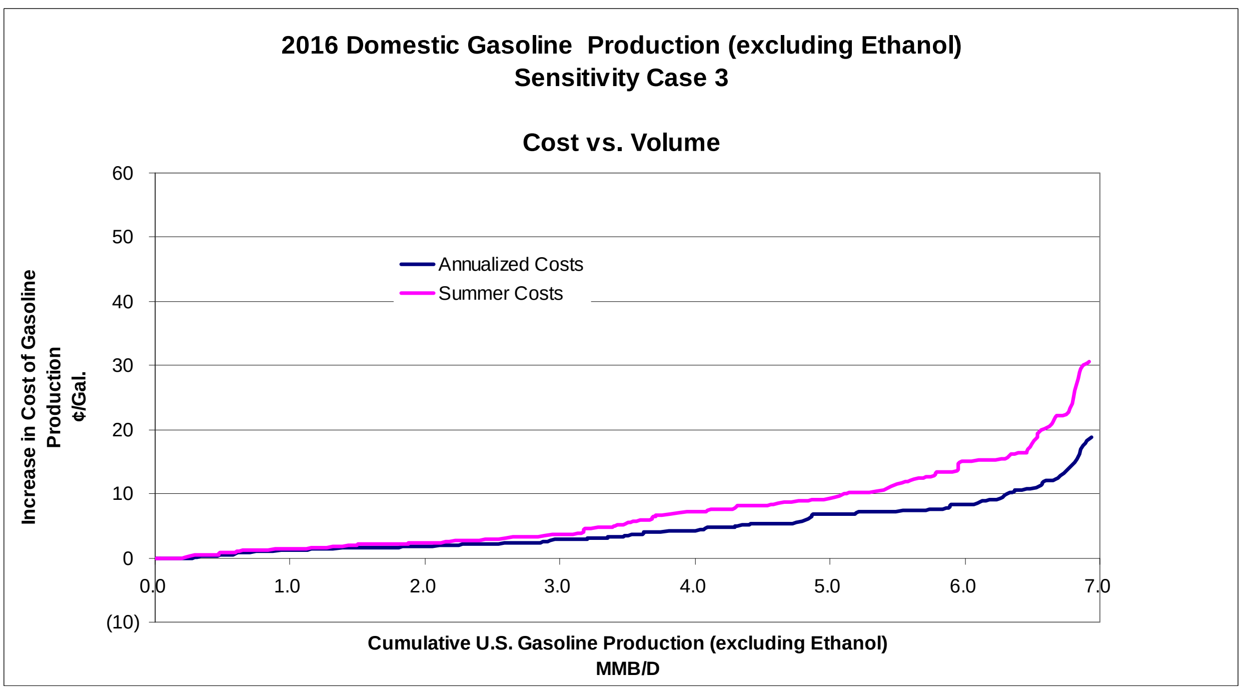
Relative to the Study Case, additional NGLs were blended into gasoline in Sensitivity Cases 2 and 3. Because some of this material need to be hydrotreated, purchased hydrogen costs were slightly higher in Sensitivity Cases 2 and 3.

In the graphs that follow, the annualized and summer individual refinery compliance costs are plotted in cents per gallon (¢/Gal.) of gasoline for the Study and Sensitivity Cases vs. cumulative barrels of gasoline supplied by U.S. refiners.









COMPARISON TO AAM REPORT

The results of this study are significantly different than those in the AAM Report. While a detailed reconciliation was not performed, there are several obvious differences in approach. The refining section of the AAM Report only considered refineries in PADDs 1, 2, and 3. According to the AAM Report, modeling was done using three aggregate refinery models, one for each of these PADDs.[33] Our analysis was done with individual models of 112 refineries, including refineries in PADDs 4 and 5. As noted in the AAM Report, the aggregate modeling approach may lead to "over-optimization" and an understatement of compliance costs.[34]

The AAM Report does not appear to consider the lost value of NGLs that would be removed from the gasoline pool, and their estimate of the volumes that would be removed seem to be much smaller than those reported herein. The AAM Report assumes that many refineries already have the capability to produce 5 ppm sulfur gasoline.[35] Our analysis indicates that most will require capital investments to produce 5 or 10 ppm sulfur gasoline. The AAM Report also uses a capital cost estimate for new FCC gasoline hydrotreater capacity that is approximately 25% of the figure used in this report.[36] The AAM analysis does not appear to include FCC feed hydrodesulfurization revamps, expansions, or new units. These items were included in our analysis.

[33] Alliance of Automobile Manufacturers, "National Clean Gasoline: An Investigation of Costs and Benefits," June 2009, p.1-2.
[34] Ibid, p. 1-23.
[35] Ibid, p.1-19.
[36] Ibid, p.1-19.

X. CONCLUSIONS

The results of our study are significantly different than those in the AAM Report. We found that implementation of standards considered in the Study and Sensitivity Cases would have a significant negative impact on gasoline production cost and supply. Four to seven refineries could shut down rather than make the investments required to meet the standards. Supplies of domestically-produced hydrocarbon gasoline are projected to decline by 8 to 19% in the summer, as a result of refinery shutdowns and the removal of NGLs from the gasoline pools. Additional hydrotreating and fractionation in the Study and Sensitivity Cases result in increased CO_2 emissions at the refineries that continue to operate.

If gasoline consumption remains at Base Case levels, gasoline imports would have to double, increasing U.S. vulnerability to supply disruptions. Distillate and NGL production at domestic refineries would increase as gasoline production declines. Additional exports of both would likely result to balance those markets.

Required compliance investments by refiners are estimated at $9 to 17 billion. On an ongoing annual basis, compliance costs are estimated at $5 to $13 billion. Allocating these costs to gasoline produced yields marginal costs of 12¢ to 25¢/Gal. on an annualized basis.

TABLE 1

U.S. Gasoline Consumption[1,2,3]

(Thousands of Barrels Per Day - Including Ethanol)

	TOTAL U.S.	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5
2005/2006 Summer[4]						
Conventional	6,107	2,019	2,169	1,087	331	501
Reformulated	2,019	1,248	360	323	-	88
CARB	1,059					1,059
TOTAL	**9,185**	**3,267**	**2,529**	**1,410**	**331**	**1,648**
2005/2006 Winter[5]						
Conventional	5,815	1,951	2,045	1,061	300	458
Reformulated	1,978	1,207	359	313	-	99
CARB	1,023					1,023
TOTAL	**8,816**	**3,158**	**2,404**	**1,374**	**300**	**1,580**
2005/2006 Annual						
Conventional	5,966	1,984	2,106	1,076	316	484
Reformulated	1,995	1,228	360	316	-	91
CARB	1,039					1,039
TOTAL	**9,000**	**3,212**	**2,466**	**1,392**	**316**	**1,614**
2016 Summer						
E85	65.4	0.4	64.7	0.1	0.0	0.2
Conventional	6,270	2,132	2,080	1,172	369	517
Reformulated	2,101	1,307	358	345	-	91
CARB	1,118					1,118
TOTAL	**9,555**	**3,440**	**2,503**	**1,517**	**369**	**1,726**
2016 Winter						
E85	62.7	0.4	62.0	0.1	0.0	0.2
Conventional	8,027	3,298	2,338	1,455	354	583
CARB	1,072	-	-	-	-	1,072
TOTAL	**9,162**	**3,299**	**2,400**	**1,455**	**354**	**1,655**
2016 Annual						
E85	64.1	0.4	63.4	0.1	0.0	0.2
Conventional	7,149	2,715	2,209	1,313	361	550
Reformulated	1,051	654	179	172	-	46
CARB	1,095	-	-	-	-	1,095
TOTAL	**9,358**	**3,369**	**2,451**	**1,486**	**361**	**1,690**

NOTES:

(1) 2005/2006 represents average consumption during 2005 and 2006 as reported in the EIA Petroleum Marketing Monthly.

(2) Annual average consumption from the EIA 2010 Annual Energy Outlook Early Release was seasonally adjusted using actual 2005/2006 consumption as reported by EIA in Petroleum Marketing Monthly.

(3) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(4) "Summer" is defined as April through September. 2005/2006 data represent average consumption during the summer periods of 2005 and 2006. Annual average consumption from the EIA 2010 Annual Energy Outlook Early Release was seasonally adjusted using actual 2005/2006 consumption as reported by EIA in Petroleum Marketing Monthly.

(5) "Winter" is defined as October through March. 2005/2006 data represent average consumption during the winter months of 2005 and 2006. Annual average consumption from the EIA 2010 Annual Energy Outlook Early Release was seasonally adjusted using actual 2005/2006 consumption as reported by EIA in Petroleum Marketing Monthly.

TABLE 2

U.S. Refining Capacities[1]

(Thousands of Barrels Per Day)

	AEO Capacity[2]	*TOTAL U.S.*	*PADD 1*	*PADD 2*	*PADD 3*	*PADD 4*	*PADD 5*
June 2009 Capacities[3]							
Crude	17,676	17,616	1,715	3,723	8,499	624	3,055
FCC		5,757	710	1,187	2,854	181	824
Hydrocracker		1,685	56	249	835	17	528
Coker		2,372	92	387	1,283	84	526
Reformer		3,523	297	838	1,715	121	553
Isom		509	16	168	169	6	151
2016 Capacities							
Crude	17,616	17,603	1,279	3,713	8,933	624	3,055
FCC		5,644	585	1,200	2,854	181	824
Hydrocracker		1,767	26	249	948	17	526
Coker		2,638	44	490	1,472	84	550
Reformer		3,605	230	840	1,861	121	553
Isom		559	11	158	219	20	151

NOTES:

(1) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(2) Table 11 - Annual Energy Outlook 2010 Early Release, December 14, 2009.

(3) Based on *PRISM* ™ 2nd Quarter 2009 estimated capacity.

TABLE 3

Base Case 2016 Summer Supply Balance[1,2]

(Thousands of Barrels Per Day - Including Ethanol)

	Ethanol[3]	*Hydrocarbon*	*TOTAL U.S.*	*PADD 1*	*PADD 2*	*PADD 3*	*PADD 4*	*PADD 5*
Domestic Refinery Gasoline Production[4]								
E85	48.4	17.0	65.4	0.4	64.7	0.1	0.0	0.2
Conventional	547.1	4,924	5,471	318	1,570	2,842	344	397
Reformulated	180.6	1,626	1,806	358	345	1,068	-	35
CARB	96.4	868	964	-	-	-	-	964
TOTAL	**873**	**7,435**	**8,307**	**677**	**1,980**	**3,910**	**344**	**1,396**
Gasoline Consumption[5]								
E85	48.4	17.0	65.4	0.4	64.7	0.1	0.0	0.2
Conventional	627.0	5,643	6,270	2,132	2,080	1,172	369	517
Reformulated	210.1	1,891	2,101	1,307	358	345	-	91
CARB	111.8	1,006	1,118	-	-	-	-	1,118
TOTAL	**997**	**8,558**	**9,555**	**3,440**	**2,503**	**1,517**	**369**	**1,726**
Domestic Refinery Over/(Under) Supply[6]								
E85		-	-	-	-	-	-	-
Conventional		(719)	(799)	(1,814)	(510)	1,670	(25)	(120)
Reformulated		(265)	(295)	(949)	(12)	723	-	(56)
CARB		(139)	(154)	-	-	-	-	(154)
TOTAL		**(1,123)**	**(1,248)**	**(2,763)**	**(523)**	**2,393**	**(25)**	**(330)**

NOTES:

(1) "Summer" is defined as April through September. Annual average consumption from the EIA 2010 Annual Energy Outlook Early Release was seasonally adjusted using actual 2005/2006 consumption as reported by the EIA in Petroleum Marketing Monthly.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) The difference between the ethanol in Domestic Refinery Gasoline Production and Gasoline Consumption is the ethanol blended into the imported gasoline blendstocks.

(4) Totals represent finished gasoline produced from refinery CBOB, RBOB, and CARBOB as determined by *PRISM* simulations and include 10 Vol.% ethanol added to domestic refinery production. Gasoline blender production, based on blendstock sources other than from domestic refiners, is not included.

(5) Total U.S. gasoline consumption is based on the full year 2016 forecast contained in the EIA 2010 Annual Energy Outlook Early Release. PADD level allocations are based on annual 2005/2006 vehicle miles traveled as reported by the U.S. Department of Transportation. Grade allocations are based on 2005/2006 average annual share of sales as reported in the Petroleum Marketing Annual.

(6) Net supply requirements are from finished gasoline and gasoline blendstocks, excluding oxygenates, either from foreign imports or non-refinery supply.

TABLE 4

Base Case 2016 Winter Supply Balance[1,2]

(Thousands of Barrels Per Day - Including Ethanol)

	Ethanol[3]	*Hydrocarbon*	*TOTAL U.S.*	*PADD 1*	*PADD 2*	*PADD 3*	*PADD 4*	*PADD 5*
Domestic Refinery Gasoline Production[4]								
E85	46.4	16.3	62.7	0.4	62.0	0.1	0.0	0.2
Conventional	701.3	6,312	7,013	657	1,827	3,787	332	411
CARB	92.2	830	922	-	-	-	-	922
TOTAL	**840**	**7,158**	**7,998**	**657**	**1,889**	**3,787**	**332**	**1,333**
Gasoline Consumption[5]								
E85	46.4	16.3	62.7	0.4	62.0	0.1	0.0	0.2
Conventional	802.7	7,225	8,027	3,298	2,338	1,455	354	583
CARB	107.2	965	1,072	-	-	-	-	1,072
TOTAL	**956**	**8,206**	**9,162**	**3,299**	**2,400**	**1,455**	**354**	**1,655**
Domestic Refinery Over/(Under) Supply[6]								
E85		-	-	-	-	-	-	-
Conventional		(913)	(1,015)	(2,641)	(511)	2,332	(22)	(172)
CARB		(135)	(150)	-	-	-	-	(150)
TOTAL		**(1,048)**	**(1,164)**	**(2,641)**	**(511)**	**2,332**	**(22)**	**(322)**

NOTES:

(1) "Winter" is defined as October through March. Annual average consumption from the EIA 2010 Annual Energy Outlook Early Release was seasonally adjusted using actual 2005/2006 consumption as reported by the EIA in Petroleum Marketing Monthly.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) The difference between the ethanol in Domestic Refinery Gasoline Production and Gasoline Consumption is the ethanol blended into the imported gasoline blendstocks.

(4) Totals represent finished gasoline produced from refinery CBOB, RBOB, and CARBOB as determined by *PRISM* simulations and include 10 Vol.% ethanol added to domestic refinery production. Gasoline blender production, based on blendstock sources other than from domestic refiners, is not included.

(5) Total U.S. gasoline consumption is based on the full year 2016 forecast contained in the EIA 2010 Annual Energy Outlook Early Release. PADD level allocations are based on annual 2005/2006 vehicle miles traveled as reported by the U.S. Department of Transportation. Grade allocations are based on 2005/2006 average annual share of sales as reported in the Petroleum Marketing

(6) Net supply requirements are from finished gasoline and gasoline blendstocks, excluding oxygenates, either from foreign imports or non-refinery supply.

TABLE 5

Base Case 2016 Annual Supply Balance[1]

(Thousands of Barrels Per Day - Including Ethanol)

	Ethanol[2]	*Hydrocarbon*	*TOTAL U.S.*	*PADD 1*	*PADD 2*	*PADD 3*	*PADD 4*	*PADD 5*
Domestic Refinery Gasoline Production[3]								
E85	47.4	16.6	64.0	0.4	63.4	0.1	-	0.2
Conventional	624.2	5,618	6,242	488	1,698	3,315	338	404
Reformulated	90.3	813	903	179	173	534	-	18
CARB	94.3	849	943	-	-	-	-	943
TOTAL	**856**	**7,296**	**8,152**	**667**	**1,934**	**3,849**	**338**	**1,364**
Gasoline Consumption[4]								
E85	47.4	16.7	64.1	0.4	63.4	0.1	0.0	0.2
Conventional	714.9	6,434	7,149	2,715	2,209	1,313	361	550
Reformulated	105.1	946	1,051	654	179	172	-	46
CARB	109.5	986	1,095	-	-	-	-	1,095
TOTAL	**977**	**8,382**	**9,358**	**3,369**	**2,451**	**1,486**	**361**	**1,690**
Domestic Refinery Over/(Under) Supply[5]								
E85		(0.0)	(0.0)	-	-	-	(0.0)	-
Conventional		(816)	(907)	(2,228)	(511)	2,001	(23)	(146)
Reformulated		(133)	(147)	(475)	(6)	362	-	(28)
CARB		(137)	(152)	-	-	-	-	(152)
TOTAL		**(1,085)**	**(1,206)**	**(2,702)**	**(517)**	**2,363**	**(23)**	**(326)**

NOTES:

(1) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(2) The difference between the ethanol in Domestic Refinery Gasoline Production and Gasoline Consumption is the ethanol blended into the imported gasoline blendstocks.

(3) Totals represent finished gasoline produced from refinery CBOB, RBOB, and CARBOB as determined by *PRISM* simulations and include 10 Vol.% ethanol added to domestic refinery production. Gasoline blender production, based on blendstock sources other than from domestic refiners, is not included.

(4) Total U.S. gasoline consumption is based on the full year 2016 forecast contained in the EIA 2010 Annual Energy Outlook Early Release. PADD level allocations are based on annual 2005/2006 vehicle miles traveled as reported by the U.S. Department of Transportation. Grade allocations are based on 2005/2006 average annual share of sales as reported in the Petroleum Marketing Annual.

(5) Net supply requirements are from finished gasoline and gasoline blendstocks, excluding oxygenates, either from foreign imports or non-refinery supply.

TABLE 6

U.S. Refining Utilization (Based on Calendar Day Capacity)[1]

	AEO Utilization[2]	*TOTAL U.S.*	*PADD 1*	*PADD 2*	*PADD 3*	*PADD 4*	*PADD 5*
2009 Utilization[3]							
Crude	80%	83%	76%	85%	83%	87%	82%
FCC		86%	81%	85%	89%	88%	82%
Hydrocracker		80%	84%	87%	74%	89%	86%
Coker		83%	71%	83%	84%	68%	85%
Reformer		86%	84%	91%	83%	94%	87%
Isom		84%	58%	89%	80%	66%	87%
2016 Utilization[4]							
Crude	83%	82%	85%	86%	80%	93%	79%
FCC		87%	82%	87%	86%	94%	89%
Hydrocracker		91%	97%	95%	91%	85%	89%
Coker		86%	90%	88%	86%	81%	86%
Reformer		83%	82%	82%	81%	93%	90%
Isom		89%	82%	95%	87%	93%	87%

NOTES:

(1) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(2) Table 11 - Annual Energy Outlook 2010 Early Release, December 14, 2009. Defined as Total Crude Supply divided by Domestic Refinery Distillation Capacity.

(3) Based on *PRISM* 2nd Quarter 2009 estimated capacity and unit rates for 4th Quarter 2008 - 3rd Quarter 2009.

(4) Based on *PRISM* simulations.

TABLE 7A

Base Case 2016 Summer Regional Finished Gasoline Qualities[1,2]
At Refinery Gate (Before Ethanol is Added)

	TOTAL U.S.	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5
Domestic Production by Crude Oil Refiners[3]						
Total Pool						
RVP, psi	7.4	7.0	8.2	7.3	8.5	6.6
Olefins, Vol.%	9.9%	12.6%	10.2%	10.6%	10.6%	6.1%
Aromatics, Vol.%	29.3%	28.4%	30.6%	29.5%	27.8%	27.7%
Benzene, Vol.%	0.58%	0.60%	0.64%	0.52%	0.95%	0.57%
Sulfur, wppm	24.7	29.8	29.9	26.9	28.9	7.8
CBOB						
RVP, psi	8.4	8.9	8.7	8.0	8.5	9.0
Olefins, Vol.%	11.6%	19.1%	10.5%	11.6%	10.6%	11.4%
Aromatics, Vol.%	33.4%	35.7%	33.8%	33.6%	27.8%	32.6%
Benzene, Vol.%	0.59%	0.60%	0.70%	0.49%	0.95%	0.57%
Sulfur, wppm	26.8	30.3	31.0	25.2	28.9	17.0
RBOB						
RVP, psi	5.4	5.3	5.6	5.3	-	5.4
Olefins, Vol.%	7.8%	6.9%	8.9%	7.8%	-	4.5%
Aromatics, Vol.%	18.6%	21.9%	16.1%	18.6%	-	8.1%
Benzene, Vol.%	0.56%	0.61%	0.35%	0.61%	-	0.63%
Sulfur, wppm	29.6	29.3	24.6	31.8	-	12.6
CARBOB						
RVP, psi	5.7	-	-	-	-	5.7
Olefins, Vol.%	4.0%	-	-	-	-	4.0%
Aromatics, Vol.%	26.5%	-	-	-	-	26.5%
Benzene, Vol.%	0.56%	-	-	-	-	0.56%
Sulfur, wppm	3.8	-	-	-	-	3.8

NOTES:

(1) "Summer" is defined as April through September.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) *PRISM* simulation results.

TABLE 7B

Base Case 2016 Summer Regional Finished Gasoline Qualities[1,2]
(includes Ethanol)

	TOTAL U.S.	*PADD 1*	*PADD 2*	*PADD 3*	*PADD 4*	*PADD 5*
Domestic Production by Crude Oil Refiners[3]						
Total Pool						
RVP, psi	8.6	8.2	9.2	8.5	9.5	7.9
Olefins, Vol.%	8.9%	11.3%	9.2%	9.5%	9.5%	5.5%
Aromatics, Vol.%	26.4%	25.6%	27.5%	26.6%	25.0%	25.0%
Benzene, Vol.%	0.53%	0.55%	0.58%	0.48%	0.86%	0.52%
Sulfur, wppm	23.2	27.7	27.8	25.2	26.9	8.0
Conventional						
RVP, psi	9.4	9.9	9.7	9.1	9.5	9.9
Olefins, Vol.%	10.5%	17.2%	9.4%	10.5%	9.5%	10.2%
Aromatics, Vol.%	30.0%	32.1%	30.4%	30.3%	25.0%	29.3%
Benzene, Vol.%	0.54%	0.55%	0.64%	0.45%	0.86%	0.52%
Sulfur, wppm	25.0	28.2	28.8	23.6	26.9	16.3
Reformulated						
RVP, psi	6.8	6.8	7.0	6.8	-	6.9
Olefins, Vol.%	7.0%	6.2%	8.0%	7.0%	-	4.0%
Aromatics, Vol.%	16.7%	19.7%	14.5%	16.8%	-	7.2%
Benzene, Vol.%	0.51%	0.55%	0.32%	0.55%	-	0.57%
Sulfur, wppm	27.5	27.3	23.1	29.5	-	12.3
CARB						
RVP, psi	7.1	-	-	-	-	7.1
Olefins, Vol.%	3.6%	-	-	-	-	3.6%
Aromatics, Vol.%	23.8%	-	-	-	-	23.8%
Benzene, Vol.%	0.51%	-	-	-	-	0.51%
Sulfur, wppm	4.5	-	-	-	-	4.5

NOTES:

(1) "Summer" is defined as April through September.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) *PRISM* simulation results.

TABLE 7C

Base Case 2016 Winter Regional Finished Gasoline Qualities[1,2]
At Refinery Gate (Before Ethanol is Added)

	TOTAL U.S.	*PADD 1*	*PADD 2*	*PADD 3*	*PADD 4*	*PADD 5*
Domestic Production by Crude Oil Refiners[3]						
Total Pool						
RVP, psi	12.2	13.9	13.5	12.5	12.8	8.7
Olefins, Vol.%	9.7%	11.4%	10.1%	10.4%	10.3%	6.1%
Aromatics, Vol.%	25.5%	24.3%	25.9%	25.4%	24.8%	25.7%
Benzene, Vol.%	0.56%	0.56%	0.63%	0.50%	0.92%	0.52%
Sulfur, wppm	23.7	28.7	28.9	25.7	28.7	7.1
CBOB						
RVP, psi	12.9	13.9	13.5	12.5	12.8	12.3
Olefins, Vol.%	10.4%	11.4%	10.1%	10.4%	10.3%	10.4%
Aromatics, Vol.%	25.6%	24.3%	25.9%	25.4%	24.8%	28.8%
Benzene, Vol.%	0.56%	0.56%	0.63%	0.50%	0.92%	0.60%
Sulfur, wppm	26.4	28.7	28.9	25.7	28.7	15.0
CARBOB						
RVP, psi	7.1	-	-	-	-	7.1
Olefins, Vol.%	4.2%	-	-	-	-	4.2%
Aromatics, Vol.%	24.3%	-	-	-	-	24.3%
Benzene, Vol.%	0.49%	-	-	-	-	0.49%
Sulfur, wppm	3.6	-	-	-	-	3.6

NOTES:

(1) "Winter" is defined as October through March.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) *PRISM* simulation results.

TABLE 7D

Base Case 2016 Winter Regional Finished Gasoline Qualities[1,2]
(includes Ethanol)

	TOTAL U.S.	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5
Domestic Production by Crude Oil Refiners[3]						
Total Pool						
RVP, psi	12.8	14.3	13.9	13.1	13.3	9.7
Olefins, Vol.%	8.7%	10.3%	9.1%	9.4%	9.3%	5.5%
Aromatics, Vol.%	22.9%	21.8%	23.3%	22.9%	22.3%	23.1%
Benzene, Vol.%	0.51%	0.51%	0.57%	0.46%	0.83%	0.48%
Sulfur, wppm	22.2	26.7	26.9	24.0	26.7	7.4
Conventional						
RVP, psi	13.4	14.3	13.9	13.1	13.3	12.9
Olefins, Vol.%	9.4%	10.3%	9.1%	9.4%	9.3%	9.4%
Aromatics, Vol.%	23.0%	21.8%	23.3%	22.9%	22.3%	25.9%
Benzene, Vol.%	0.51%	0.51%	0.57%	0.46%	0.83%	0.54%
Sulfur, wppm	24.6	26.7	26.9	24.0	26.7	14.4
CARB						
RVP, psi	8.3	-	-	-	-	8.3
Olefins, Vol.%	3.8%	-	-	-	-	3.8%
Aromatics, Vol.%	21.9%	-	-	-	-	21.9%
Benzene, Vol.%	0.45%	-	-	-	-	0.45%
Sulfur, wppm	4.3	-	-	-	-	4.3

NOTES:

(1) "Winter" is defined as October through March.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) *PRISM* simulation results.

TABLE 8

Base Case 2016 Summer Production[1,2]

(Thousands of Barrels Per Day - Including Ethanol)

	TOTAL U.S.	*PADD 1*	*PADD 2*	*PADD 3*	*PADD 4*	*PADD 5*
Domestic Production by Crude Oil Refiners[3]						
E85 Gasoline	65.4	0.4	64.7	0.1	0.0	0.2
Conventional Gasoline	5,471	318	1,570	2,842	344	397
Reformulated Gasoline	1,806	358	345	1,068	-	35
CARB Gasoline	964	-	-	-	-	964
Jet Fuel	1,488	79	263	666	41	439
Distillates	4,245	331	893	2,345	170	505
Pentanes	92	2	-	30	-	60
Other[4]	4,126	306	722	2,184	128	786
TOTAL	**18,258**	**1,395**	**3,858**	**9,136**	**683**	**3,186**

NOTES:

(1) "Summer" is defined as April through September. Annual average consumption from the EIA 2010 Annual Energy Outlook Early Release was seasonally adjusted using actual 2005/2006 consumption as reported by the EIA in Petroleum Marketing Monthly.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) Totals represent finished gasoline produced from refinery CBOB, RBOB, and CARBOB as determined by *PRISM* simulations and include 10 Vol.% ethanol added to refinery production. Gasoline blender production, based on blendstock sources other than from domestic refiners, is not included.

(4) Includes LPG, residual fuel oil, aviation gasoline, petrochemical feedstocks, lubricants, waxes, asphalt, road oil, still gas, special naphthas, petroleum coke, and miscellaneous petroleum products.

TABLE 9

Base Case 2016 Winter Production[1,2]

(Thousands of Barrels Per Day - Including Ethanol)

	TOTAL U.S.	*PADD 1*	*PADD 2*	*PADD 3*	*PADD 4*	*PADD 5*
Domestic Production by Crude Oil Refiners[3]						
E85 Gasoline	62.7	0.4	62.0	0.1	0.0	0.2
Conventional Gasoline	7,013	657	1,827	3,787	332	411
CARB Gasoline	922	-	-	-	-	922
Jet Fuel	1,488	96	279	668	39	405
Distillates	4,383	334	967	2,421	173	488
Pentanes	18	-	-	6	-	12
Other[4]	3,284	258	572	1,711	114	628
TOTAL	**17,170**	**1,345**	**3,708**	**8,594**	**657**	**2,866**

NOTES:

(1) "Winter" is defined as October through March. Annual average consumption from the EIA 2010 Annual Energy Outlook Early Release was seasonally adjusted using actual 2005/2006 consumption as reported by the EIA in Petroleum Marketing Monthly.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) Totals represent finished gasoline produced from refinery CBOB, RBOB, and CARBOB as determined by *PRISM* simulations and include 10 Vol.% ethanol added to refinery production. Gasoline blender production, based on blendstock sources other than from domestic refiners, is not included.

(4) Includes LPG, residual fuel oil, aviation gasoline, petrochemical feedstocks, lubricants, waxes, asphalt, road oil, still gas, special naphthas, petroleum coke, and miscellaneous petroleum products.

TABLE 10

Study Case 2016 Summer Supply Balance[1,2]

(Thousands of Barrels Per Day - Including Ethanol)

	Ethanol[3]	*Hydrocarbon*	*TOTAL U.S.*	*PADD 1*	*PADD 2*	*PADD 3*	*PADD 4*	*PADD 5*
Domestic Refinery Gasoline Production[4]								
E85	48.4	17.0	65.4	0.4	64.7	0.1	0.0	0.2
Lower Sulfur, Lower RVP Gasoline	609.4	5,484	6,094	581	1,477	3,350	287	399
CARB	86.2	776	862	-	-	-	-	862
TOTAL	**744**	**6,278**	**7,022**	**581**	**1,541**	**3,350**	**287**	**1,262**
Gasoline Consumption[5]								
E85	48.4	17.0	65.4	0.4	64.7	0.1	0.0	0.2
Lower Sulfur, Lower RVP Gasoline	837.2	7,534	8,372	3,440	2,438	1,517	369	608
CARB	111.8	1,006	1,118	-	-	-	-	1,118
TOTAL	**997**	**8,558**	**9,555**	**3,440**	**2,503**	**1,517**	**369**	**1,726**
Domestic Refinery Over/(Under) Supply[6]								
E85		-	-	-	-	-	-	-
Lower Sulfur, Lower RVP Gasoline		(2,050)	(2,278)	(2,859)	(961)	1,833	(82)	(209)
CARB		(230)	(256)	-	-	-	-	(256)
TOTAL		**(2,280)**	**(2,533)**	**(2,859)**	**(961)**	**1,833**	**(82)**	**(464)**

NOTES:

(1) "Summer" is defined as April through September. Annual average consumption from the EIA 2010 Annual Energy Outlook Early Release was seasonally adjusted using actual 2005/2006 consumption as reported by the EIA in Petroleum Marketing Monthly.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) The difference between the ethanol in Domestic Refinery Gasoline Production and Gasoline Consumption is the ethanol blended into the imported gasoline blendstocks.

(4) Totals represent finished gasoline produced from refinery CBOB, RBOB, and CARBOB as determined by *PRISM* simulations and include 10 Vol.% ethanol added to domestic refinery production. Gasoline blender production, based on blendstock sources other than from domestic refiners, is not included.

(5) Total U.S. gasoline consumption is based on the full year 2016 forecast contained in the EIA 2010 Annual Energy Outlook Early Release. PADD level allocations are based on annual 2005/2006 vehicle miles traveled as reported by the U.S. Department of Transportation. Grade allocations are based on 2005/2006 average annual share of sales as reported in the Petroleum Marketing Annual.

(6) Net supply requirements are from finished gasoline and gasoline blendstocks, excluding oxygenates, either from foreign imports or non-refinery supply.

TABLE 11

Study Case 2016 Winter Supply Balance[1,2]

(Thousands of Barrels Per Day - Including Ethanol)

	Ethanol [3]	*Hydrocarbon*	*TOTAL U.S.*	*PADD 1*	*PADD 2*	*PADD 3*	*PADD 4*	*PADD 5*
Domestic Refinery Gasoline Production[4]								
E85	46.4	16.3	62.7	0.4	62.0	0.1	0.0	0.2
Lower Sulfur, Lower RVP Gasoline	687.1	6,184	6,871	657	1,733	3,787	332	363
CARB	92.2	830	922	-	-	-	-	922
TOTAL	**826**	**7,030**	**7,856**	**657**	**1,795**	**3,787**	**332**	**1,285**
Gasoline Consumption[5]								
E85	46.4	16.3	62.7	0.4	62.0	0.1	0.0	0.2
Lower Sulfur, Lower RVP Gasoline	802.7	7,225	8,027	3,298	2,338	1,455	354	583
CARB	107.2	965	1,072	-	-	-	-	1,072
TOTAL	**956**	**8,206**	**9,162**	**3,299**	**2,400**	**1,455**	**354**	**1,655**
Domestic Refinery Over/(Under) Supply[6]								
E85		-	-	-	-	-	-	-
Lower Sulfur, Lower RVP Gasoline		(1,041)	(1,156)	(2,641)	(605)	2,332	(22)	(220)
CARB		(135)	(150)	-	-	-	-	(150)
TOTAL		**(1,176)**	**(1,306)**	**(2,641)**	**(605)**	**2,332**	**(22)**	**(370)**

NOTES:

(1) "Winter" is defined as October through March. Annual average consumption from the EIA 2010 Annual Energy Outlook Early Release was seasonally adjusted using actual 2005/2006 consumption as reported by the EIA in Petroleum Marketing Monthly.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) The difference between the ethanol in Domestic Refinery Gasoline Production and Gasoline Consumption is the ethanol blended into the imported gasoline blendstocks.

(4) Totals represent finished gasoline produced from refinery CBOB, RBOB, and CARBOB as determined by *PRISM* simulations and include 10 Vol.% ethanol added to domestic refinery production. Gasoline blender production, based on blendstock sources other than from domestic refiners, is not included.

(5) Total U.S. gasoline consumption is based on the full year 2016 forecast contained in the EIA 2010 Annual Energy Outlook Early Release. PADD level allocations are based on annual 2005/2006 vehicle miles traveled as reported by the U.S. Department of Transportation. Grade allocations are based on 2005/2006 average annual share of sales as reported in the Petroleum Marketing Annual.

(6) Net supply requirements are from finished gasoline and gasoline blendstocks, excluding oxygenates, either from foreign imports or non-refinery supply.

TABLE 12A

Study Case 2016 Summer Regional Finished Gasoline Qualities[1,2]
At Refinery Gate (Before Ethanol is Added)

	TOTAL U.S.	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5
Domestic Production by Crude Oil Refiners[3]						
Total Pool						
RVP, psi	5.5	5.4	5.4	5.4	5.4	5.5
Olefins, Vol.%	7.2%	8.3%	7.6%	7.6%	8.8%	4.6%
Aromatics, Vol.%	32.4%	31.7%	33.7%	33.5%	31.4%	28.4%
Benzene, Vol.%	0.64%	0.73%	0.77%	0.57%	0.82%	0.59%
Sulfur, wppm	10.7	11.7	12.0	12.2	12.6	4.6
Lower Sulfur, Lower RVP Gasoline						
RVP, psi	5.4	5.4	5.4	5.4	5.4	5.4
Olefins, Vol.%	7.6%	8.3%	7.6%	7.6%	8.8%	5.8%
Aromatics, Vol.%	33.1%	31.7%	33.7%	33.5%	31.4%	31.0%
Benzene, Vol.%	0.65%	0.73%	0.77%	0.57%	0.82%	0.70%
Sulfur, wppm	11.7	11.7	12.0	12.2	12.6	6.8
CARBOB						
RVP, psi	5.6	-	-	-	-	5.6
Olefins, Vol.%	4.0%	-	-	-	-	4.0%
Aromatics, Vol.%	27.2%	-	-	-	-	27.2%
Benzene, Vol.%	0.53%	-	-	-	-	0.53%
Sulfur, wppm	3.5	-	-	-	-	3.5

NOTES:

(1) "Summer" is defined as April through September.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) *PRISM* simulation results.

TABLE 12B

Study Case 2016 Summer Regional Finished Gasoline Qualities[1,2]
(includes Ethanol)

	TOTAL U.S.	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5
Domestic Production by Crude Oil Refiners[3]						
Total Pool						
RVP, psi	6.9	6.9	6.9	6.9	6.9	7.0
Olefins, Vol.%	6.5%	7.4%	6.9%	6.9%	7.9%	4.1%
Aromatics, Vol.%	29.1%	28.5%	30.3%	30.1%	28.3%	25.6%
Benzene, Vol.%	0.58%	0.67%	0.70%	0.52%	0.75%	0.54%
Sulfur, wppm	10.7	11.5	11.8	11.9	12.3	5.1
Lower Sulfur, Lower RVP Gasoline						
RVP, psi	6.9	6.9	6.9	6.9	6.9	6.9
Olefins, Vol.%	6.9%	7.4%	6.9%	6.9%	7.9%	5.2%
Aromatics, Vol.%	29.8%	28.5%	30.3%	30.1%	28.3%	27.9%
Benzene, Vol.%	0.60%	0.67%	0.70%	0.52%	0.75%	0.64%
Sulfur, wppm	11.6	11.5	11.8	11.9	12.3	7.1
CARBOB						
RVP, psi	7.0	-	-	-	-	7.0
Olefins, Vol.%	3.6%	-	-	-	-	3.6%
Aromatics, Vol.%	24.5%	-	-	-	-	24.5%
Benzene, Vol.%	0.49%	-	-	-	-	0.49%
Sulfur, wppm	4.2	-	-	-	-	4.2

NOTES:

(1) "Summer" is defined as April through September.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) *PRISM* simulation results.

TABLE 12C

Study Case 2016 Winter Regional Finished Gasoline Qualities[1,2]
At Refinery Gate (Before Ethanol is Added)

	TOTAL U.S.	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5
Domestic Production by Crude Oil Refiners[3]						
Total Pool						
RVP, psi	12.2	13.9	13.5	12.5	12.8	8.5
Olefins, Vol.%	9.7%	11.4%	10.1%	10.4%	10.3%	6.0%
Aromatics, Vol.%	25.4%	24.3%	25.5%	25.4%	24.8%	25.7%
Benzene, Vol.%	0.56%	0.56%	0.65%	0.50%	0.92%	0.53%
Sulfur, wppm	5.9	6.3	6.3	6.3	6.3	4.2
Lower Sulfur, Lower RVP Gasoline						
RVP, psi	12.9	13.9	13.5	12.5	12.8	12.0
Olefins, Vol.%	10.4%	11.4%	10.1%	10.4%	10.3%	10.6%
Aromatics, Vol.%	25.5%	24.3%	25.5%	25.4%	24.8%	29.0%
Benzene, Vol.%	0.57%	0.56%	0.65%	0.50%	0.92%	0.61%
Sulfur, wppm	6.3	6.3	6.3	6.3	6.3	5.7
CARBOB						
RVP, psi	7.1	-	-	-	-	7.1
Olefins, Vol.%	4.2%	-	-	-	-	4.2%
Aromatics, Vol.%	24.3%	-	-	-	-	24.3%
Benzene, Vol.%	0.49%	-	-	-	-	0.49%
Sulfur, wppm	3.6	-	-	-	-	3.6

NOTES:
(1) "Winter" is defined as October through March.
(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"
(3) *PRISM* simulation results.

TABLE 12D

Study Case 2016 Winter Regional Finished Gasoline Qualities[1,2]
(includes Ethanol)

	TOTAL U.S.	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5
Domestic Production by Crude Oil Refiners[3]						
Total Pool						
RVP, psi	12.8	14.3	14.0	13.1	13.3	9.5
Olefins, Vol.%	8.7%	10.3%	9.1%	9.3%	9.3%	5.4%
Aromatics, Vol.%	22.8%	21.8%	23.0%	22.9%	22.3%	23.1%
Benzene, Vol.%	0.51%	0.51%	0.59%	0.46%	0.83%	0.48%
Sulfur, wppm	6.4	6.7	6.7	6.7	6.7	4.8
Lower Sulfur, Lower RVP Gasoline						
RVP, psi	13.4	14.3	14.0	13.1	13.3	12.6
Olefins, Vol.%	9.4%	10.3%	9.1%	9.3%	9.3%	9.5%
Aromatics, Vol.%	22.9%	21.8%	23.0%	22.9%	22.3%	26.1%
Benzene, Vol.%	0.52%	0.51%	0.59%	0.46%	0.83%	0.56%
Sulfur, wppm	6.7	6.7	6.7	6.7	6.7	6.1
CARBOB						
RVP, psi	8.3	-	-	-	-	8.3
Olefins, Vol.%	3.8%	-	-	-	-	3.8%
Aromatics, Vol.%	21.9%	-	-	-	-	21.9%
Benzene, Vol.%	0.45%	-	-	-	-	0.45%
Sulfur, wppm	4.3	-	-	-	-	4.3

NOTES:

(1) "Winter" is defined as October through March.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) *PRISM* simulation results.

TABLE 13

Study Case 2016 Summer Production[1,2]

(Thousands of Barrels Per Day - Including Ethanol)

	TOTAL U.S.	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5
Domestic Production by Crude Oil Refiners[3]						
E85 Gasoline	65.4	0.4	64.7	0.1	0.0	0.2
Lower Sulfur, Lower RVP Gasoline	6,094	581	1,477	3,350	287	399
CARB Gasoline	862	-	-	-	-	862
Jet Fuel	1,494	79	273	672	41	428
Distillates	4,418	353	958	2,434	179	494
Pentanes	746	62	172	369	24	120
Other[4]	4,070	312	683	2,200	134	742
TOTAL	**17,750**	**1,387**	**3,626**	**9,026**	**665**	**3,046**

NOTES:

(1) "Summer" is defined as April through September. Annual average consumption from the EIA 2010 Annual Energy Outlook Early Release was seasonally adjusted using actual 2005/2006 consumption as reported by the EIA in Petroleum Marketing Monthly.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) Totals represent finished gasoline produced from refinery CBOB, RBOB, and CARBOB as determined by *PRISM* simulations and include 10 Vol.% ethanol added to refinery production. Gasoline blender production, based on blendstock sources other than from domestic refiners, is not included.

(4) Includes LPG, residual fuel oil, aviation gasoline, petrochemical feedstocks, lubricants, waxes, asphalt, road oil, still gas, special naphthas, petroleum coke, and miscellaneous petroleum products.

TABLE 14

Study Case 2016 Winter Production[1,2]

(Thousands of Barrels Per Day - Including Ethanol)

	TOTAL U.S.	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5
Domestic Production by Crude Oil Refiners[3]						
E85 Gasoline	62.7	0.4	62.0	0.1	0.0	0.2
Lower Sulfur, Lower RVP Gasoline	6,871	657	1,733	3,787	332	363
CARB Gasoline	922	-	-	-	-	922
Jet Fuel	1,474	96	265	668	39	405
Distillates	4,362	334	947	2,421	173	488
Pentanes	18	-	-	6	-	12
Other[4]	3,196	258	534	1,711	114	579
TOTAL	**16,906**	**1,345**	**3,542**	**8,594**	**657**	**2,768**

NOTES:

(1) "Winter" is defined as October through March. Annual average consumption from the EIA 2010 Annual Energy Outlook Early Release was seasonally adjusted using actual 2005/2006 consumption as reported by the EIA in Petroleum Marketing Monthly.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) Totals represent finished gasoline produced from refinery CBOB, RBOB, and CARBOB as determined by *PRISM* simulations and include 10 Vol.% ethanol added to refinery production. Gasoline blender production, based on blendstock sources other than from domestic refiners, is not included.

(4) Includes LPG, residual fuel oil, aviation gasoline, petrochemical feedstocks, lubricants, waxes, asphalt, road oil, still gas, special naphthas, petroleum coke, and miscellaneous petroleum products.

TABLE 15

Sensitivity Case 1 2016 Summer Supply Balance[1,2]

(Thousands of Barrels Per Day - Including Ethanol)

	Ethanol [3]	*Hydrocarbon*	*TOTAL U.S.*	*PADD 1*	*PADD 2*	*PADD 3*	*PADD 4*	*PADD 5*
Domestic Refinery Gasoline Production[4]								
E85	48.4	17.0	65.4	0.4	64.7	0.1	0.0	0.2
Lower Sulfur, Lower RVP Gasoline	586.3	5,276	5,863	568	1,434	3,183	284	394
CARB	84.9	765	849	-	-	-	-	849
TOTAL	**720**	**6,058**	**6,777**	**568**	**1,499**	**3,183**	**284**	**1,244**
Gasoline Consumption[5]								
E85	48.4	17.0	65.4	0.4	64.7	0.1	0.0	0.2
Lower Sulfur, Lower RVP Gasoline	837.2	7,534	8,372	3,440	2,438	1,517	369	608
CARB	111.8	1,006	1,118	-	-	-	-	1,118
TOTAL	**997**	**8,558**	**9,555**	**3,440**	**2,503**	**1,517**	**369**	**1,726**
Domestic Refinery Over/(Under) Supply[6]								
E85		-	-	-	-	-	-	-
Lower Sulfur, Lower RVP Gasoline		(2,258)	(2,509)	(2,872)	(1,004)	1,666	(85)	(214)
CARB		(242)	(269)	-	-	-	-	(269)
TOTAL		**(2,500)**	**(2,778)**	**(2,872)**	**(1,004)**	**1,666**	**(85)**	**(482)**

NOTES:

(1) "Summer" is defined as April through September. Annual average consumption from the EIA 2010 Annual Energy Outlook Early Release was seasonally adjusted using actual 2005/2006 consumption as reported by the EIA in Petroleum Marketing Monthly.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) The difference between the ethanol in Domestic Refinery Gasoline Production and Gasoline Consumption is the ethanol blended into the imported gasoline blendstocks.

(4) Totals represent finished gasoline produced from refinery CBOB, RBOB, and CARBOB as determined by *PRISM* simulations and include 10 Vol.% ethanol added to domestic refinery production. Gasoline blender production, based on blendstock sources other than from domestic refiners, is not included.

(5) Total U.S. gasoline consumption is based on the full year 2016 forecast contained in the EIA 2010 Annual Energy Outlook Early Release. PADD level allocations are based on annual 2005/2006 vehicle miles traveled as reported by the U.S. Department of Transportation. Grade allocations are based on 2005/2006 average annual share of sales as reported in the Petroleum Marketing Annual.

(6) Net supply requirements are from finished gasoline and gasoline blendstocks, excluding oxygenates, either from foreign imports or non-refinery supply.

TABLE 16

Sensitivity Case 1 2016 Winter Supply Balance[1,2]

(Thousands of Barrels Per Day - Including Ethanol)

	Ethanol[3]	*Hydrocarbon*	*TOTAL U.S.*	*PADD 1*	*PADD 2*	*PADD 3*	*PADD 4*	*PADD 5*
Domestic Refinery Gasoline Production[4]								
E85	46.4	16.3	62.7	0.4	62.0	0.1	0.0	0.2
Lower Sulfur, Lower RVP Gasoline	674.5	6,071	6,745	657	1,701	3,694	332	363
CARB	92.2	830	922	-	-	-	-	922
TOTAL	**813**	**6,917**	**7,730**	**657**	**1,763**	**3,694**	**332**	**1,285**
Gasoline Consumption[5]								
E85	46.4	16.3	62.7	0.4	62.0	0.1	0.0	0.2
Lower Sulfur, Lower RVP Gasoline	802.7	7,225	8,027	3,298	2,338	1,455	354	583
CARB	107.2	965	1,072	-	-	-	-	1,072
TOTAL	**956**	**8,206**	**9,162**	**3,299**	**2,400**	**1,455**	**354**	**1,655**
Domestic Refinery Over/(Under) Supply[6]								
E85		-	-	-	-	-	-	-
Lower Sulfur, Lower RVP Gasoline		(1,154)	(1,282)	(2,641)	(637)	2,239	(22)	(220)
CARB		(135)	(150)	-	-	-	-	(150)
TOTAL		**(1,289)**	**(1,432)**	**(2,641)**	**(637)**	**2,239**	**(22)**	**(370)**

NOTES:

(1) "Winter" is defined as October through March. Annual average consumption from the EIA 2010 Annual Energy Outlook Early Release was seasonally adjusted using actual 2005/2006 consumption as reported by the EIA in Petroleum Marketing Monthly.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) The difference between the ethanol in Domestic Refinery Gasoline Production and Gasoline Consumption is the ethanol blended into the imported gasoline blendstocks.

(4) Totals represent finished gasoline produced from refinery CBOB, RBOB, and CARBOB as determined by *PRISM* simulations and include 10 Vol.% ethanol added to domestic refinery production. Gasoline blender production, based on blendstock sources other than from domestic refiners, is not included.

(5) Total U.S. gasoline consumption is based on the full year 2016 forecast contained in the EIA 2010 Annual Energy Outlook Early Release. PADD level allocations are based on annual 2005/2006 vehicle miles traveled as reported by the U.S. Department of Transportation. Grade allocations are based on 2005/2006 average annual share of sales as reported in the Petroleum Marketing

(6) Net supply requirements are from finished gasoline and gasoline blendstocks, excluding oxygenates, either from foreign imports or non-refinery supply.

TABLE 17A

Sensitivity Case 1 2016 Summer Regional Finished Gasoline Qualities[1,2]
At Refinery Gate (Before Ethanol is Added)

	TOTAL U.S.	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5
Domestic Production by Crude Oil Refiners[3]						
Total Pool						
RVP, psi	5.5	5.4	5.4	5.4	5.4	5.5
Olefins, Vol.%	7.1%	8.0%	7.4%	7.8%	7.8%	4.3%
Aromatics, Vol.%	32.8%	31.8%	33.8%	34.0%	31.6%	29.1%
Benzene, Vol.%	0.65%	0.74%	0.77%	0.59%	0.85%	0.58%
Sulfur, wppm	4.9	5.1	5.1	5.3	5.2	3.7
Lower Sulfur, Lower RVP Gasoline						
RVP, psi	5.4	5.4	5.4	5.4	5.4	5.4
Olefins, Vol.%	7.5%	8.0%	7.4%	7.8%	7.8%	5.3%
Aromatics, Vol.%	33.8%	31.8%	33.8%	34.0%	31.6%	36.7%
Benzene, Vol.%	0.66%	0.74%	0.77%	0.59%	0.85%	0.68%
Sulfur, wppm	5.2	5.1	5.1	5.3	5.2	4.4
CARBOB						
RVP, psi	5.6	-	-	-	-	5.6
Olefins, Vol.%	3.8%	-	-	-	-	3.8%
Aromatics, Vol.%	25.6%	-	-	-	-	25.6%
Benzene, Vol.%	0.53%	-	-	-	-	0.53%
Sulfur, wppm	3.4	-	-	-	-	3.4

NOTES:

(1) "Summer" is defined as April through September.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) *PRISM* simulation results.

TABLE 17B

Sensitivity Case 1 2016 Summer Regional Finished Gasoline Qualities[1,2] (includes Ethanol)

	TOTAL U.S.	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5
Domestic Production by Crude Oil Refiners[3]						
Total Pool						
RVP, psi	6.9	6.9	6.9	6.9	6.9	7.0
Olefins, Vol.%	6.4%	7.2%	6.6%	7.0%	7.0%	3.9%
Aromatics, Vol.%	29.5%	28.6%	30.5%	30.6%	28.4%	26.2%
Benzene, Vol.%	0.59%	0.68%	0.70%	0.53%	0.77%	0.52%
Sulfur, wppm	5.5	5.6	5.6	5.8	5.7	4.4
Lower Sulfur, Lower RVP Gasoline						
RVP, psi	6.9	6.9	6.9	6.9	6.9	6.9
Olefins, Vol.%	6.8%	7.2%	6.6%	7.0%	7.0%	4.8%
Aromatics, Vol.%	30.4%	28.6%	30.5%	30.6%	28.4%	33.0%
Benzene, Vol.%	0.60%	0.68%	0.70%	0.53%	0.77%	0.62%
Sulfur, wppm	5.6	5.6	5.6	5.8	5.7	4.9
CARBOB						
RVP, psi	7.0	-	-	-	-	7.0
Olefins, Vol.%	3.4%	-	-	-	-	3.4%
Aromatics, Vol.%	23.0%	-	-	-	-	23.0%
Benzene, Vol.%	0.48%	-	-	-	-	0.48%
Sulfur, wppm	4.1	-	-	-	-	4.1

NOTES:

(1) "Summer" is defined as April through September.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) *PRISM* simulation results.

TABLE 17C

Sensitivity Case 1 2016 Winter Regional Finished Gasoline Qualities[1,2]
At Refinery Gate (Before Ethanol is Added)

	TOTAL U.S.	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5
Domestic Production by Crude Oil Refiners[3]						
Total Pool						
RVP, psi	12.2	13.9	13.5	12.5	12.8	8.5
Olefins, Vol.%	9.7%	11.4%	10.1%	10.4%	10.3%	6.0%
Aromatics, Vol.%	25.3%	24.3%	25.5%	25.3%	24.8%	25.7%
Benzene, Vol.%	0.56%	0.56%	0.64%	0.50%	0.92%	0.53%
Sulfur, wppm	3.4	3.3	3.4	3.3	3.3	3.5
Lower Sulfur, Lower RVP Gasoline						
RVP, psi	12.9	13.9	13.5	12.5	12.8	12.0
Olefins, Vol.%	10.4%	11.4%	10.1%	10.4%	10.3%	10.6%
Aromatics, Vol.%	25.5%	24.3%	25.5%	25.3%	24.8%	29.0%
Benzene, Vol.%	0.57%	0.56%	0.64%	0.50%	0.92%	0.61%
Sulfur, wppm	3.3	3.3	3.4	3.3	3.3	3.2
CARBOB						
RVP, psi	7.1	-	-	-	-	7.1
Olefins, Vol.%	4.2%	-	-	-	-	4.2%
Aromatics, Vol.%	24.3%	-	-	-	-	24.3%
Benzene, Vol.%	0.49%	-	-	-	-	0.49%
Sulfur, wppm	3.6	-	-	-	-	3.6

NOTES:

(1) "Winter" is defined as October through March.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) *PRISM* simulation results.

TABLE 17D

Sensitivity Case 1 2016 Winter Regional Finished Gasoline Qualities[1,2]
(includes Ethanol)

	TOTAL U.S.	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5
Domestic Production by Crude Oil Refiners[3]						
Total Pool						
RVP, psi	12.8	14.3	13.9	13.1	13.3	9.5
Olefins, Vol.%	8.7%	10.3%	9.1%	9.4%	9.3%	5.4%
Aromatics, Vol.%	22.8%	21.8%	23.0%	22.8%	22.3%	23.1%
Benzene, Vol.%	0.51%	0.51%	0.59%	0.46%	0.83%	0.48%
Sulfur, wppm	4.1	4.1	4.0	4.0	4.1	4.2
Lower Sulfur, Lower RVP Gasoline						
RVP, psi	13.4	14.3	13.9	13.1	13.3	12.6
Olefins, Vol.%	9.4%	10.3%	9.1%	9.4%	9.3%	9.5%
Aromatics, Vol.%	22.9%	21.8%	23.0%	22.8%	22.3%	26.1%
Benzene, Vol.%	0.52%	0.51%	0.59%	0.46%	0.83%	0.56%
Sulfur, wppm	4.0	4.1	4.0	4.0	4.1	3.9
CARBOB						
RVP, psi	8.3	-	-	-	-	8.3
Olefins, Vol.%	3.8%	-	-	-	-	3.8%
Aromatics, Vol.%	21.9%	-	-	-	-	21.9%
Benzene, Vol.%	0.45%	-	-	-	-	0.45%
Sulfur, wppm	4.3	-	-	-	-	4.3

NOTES:

(1) "Winter" is defined as October through March.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) *PRISM* simulation results.

TABLE 18

Sensitivity Case 1 2016 Summer Production[1,2]

(Thousands of Barrels Per Day - Including Ethanol)

	TOTAL U.S.	*PADD 1*	*PADD 2*	*PADD 3*	*PADD 4*	*PADD 5*
Domestic Production by Crude Oil Refiners[3]						
E85 Gasoline	65.4	0.4	64.7	0.1	0.0	0.2
Lower Sulfur, Lower RVP Gasoline	5,863	568	1,434	3,183	284	394
CARB Gasoline	849	-	-	-	-	849
Jet Fuel	1,480	79	273	673	41	414
Distillates	4,365	354	949	2,390	184	487
Pentanes	751	64	170	374	25	118
Other[4]	4,170	326	671	2,224	133	816
TOTAL	**17,543**	**1,391**	**3,562**	**8,844**	**668**	**3,078**

NOTES:

(1) "Summer" is defined as April through September. Annual average consumption from the EIA 2010 Annual Energy Outlook Early Release was seasonally adjusted using actual 2005/2006 consumption as reported by the EIA in Petroleum Marketing Monthly.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) Totals represent finished gasoline produced from refinery CBOB, RBOB, and CARBOB as determined by *PRISM* simulations and include 10 Vol.% ethanol added to refinery production. Gasoline blender production, based on blendstock sources other than from domestic refiners, is not included.

(4) Includes LPG, residual fuel oil, aviation gasoline, petrochemical feedstocks, lubricants, waxes, asphalt, road oil, still gas, special naphthas, petroleum coke, and miscellaneous petroleum products.

TABLE 19

Sensitivity Case 1 2016 Winter Production[1,2]

(Thousands of Barrels Per Day - Including Ethanol)

	TOTAL U.S.	*PADD 1*	*PADD 2*	*PADD 3*	*PADD 4*	*PADD 5*
Domestic Production by Crude Oil Refiners[3]						
E85 Gasoline	62.7	0.4	62.0	0.1	0.0	0.2
Lower Sulfur, Lower RVP Gasoline	6,745	657	1,701	3,694	332	363
CARB Gasoline	922	-	-	-	-	922
Jet Fuel	1,448	96	256	662	39	395
Distillates	4,275	334	931	2,364	173	473
Pentanes	18	-	-	6	-	12
Other[4]	3,184	258	521	1,686	114	605
TOTAL	**16,654**	**1,345**	**3,470**	**8,412**	**657**	**2,769**

NOTES:

(1) "Winter" is defined as October through March. Annual average consumption from the EIA 2010 Annual Energy Outlook Early Release was seasonally adjusted using actual 2005/2006 consumption as reported by the EIA in Petroleum Marketing Monthly.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) Totals represent finished gasoline produced from refinery CBOB, RBOB, and CARBOB as determined by *PRISM* simulations and include 10 Vol.% ethanol added to refinery production. Gasoline blender production, based on blendstock sources other than from domestic refiners, is not included.

(4) Includes LPG, residual fuel oil, aviation gasoline, petrochemical feedstocks, lubricants, waxes, asphalt, road oil, still gas, special naphthas, petroleum coke, and miscellaneous petroleum products.

TABLE 20

Sensitivity Case 2 2016 Summer Supply Balance[1,2]

(Thousands of Barrels Per Day - Including Ethanol)

	Ethanol [3]	*Hydrocarbon*	*TOTAL U.S.*	*PADD 1*	*PADD 2*	*PADD 3*	*PADD 4*	*PADD 5*
Domestic Refinery Gasoline Production[4]								
E85	48.4	17.0	65.4	0.4	64.7	0.1	0.0	0.2
Lower Sulfur, Lower RVP Gasoline - C	475.1	4,276	4,751	319	1,153	2,589	310	381
Lower Sulfur, Lower RVP Gasoline - R	165.3	1,487	1,653	284	421	909	-	39
CARB	86.9	782	869	-	-	-	-	869
TOTAL	**776**	**6,562**	**7,338**	**603**	**1,639**	**3,498**	**310**	**1,289**
Gasoline Consumption[5]								
E85	48.4	17.0	65.4	0.4	64.7	0.1	0.0	0.2
Lower Sulfur, Lower RVP Gasoline - C	627.0	5,643	6,270	2,132	2,080	1,172	369	517
Lower Sulfur, Lower RVP Gasoline - R	210.1	1,891	2,101	1,307	358	345	-	91
CARB	111.8	1,006	1,118	-	-	-	-	1,118
TOTAL	**997**	**8,558**	**9,555**	**3,440**	**2,503**	**1,517**	**369**	**1,726**
Domestic Refinery Over/(Under) Supply[6]								
E85		-	-	-	-	-	-	-
Lower Sulfur, Lower RVP Gasoline - C		(1,368)	(1,520)	(1,814)	(927)	1,416	(59)	(136)
Lower Sulfur, Lower RVP Gasoline - R		(404)	(449)	(1,024)	63	564	-	(53)
CARB		(224)	(249)	-	-	-	-	(249)
TOTAL		**(1,996)**	**(2,217)**	**(2,837)**	**(864)**	**1,980**	**(59)**	**(437)**

NOTES:

(1) "Summer" is defined as April through September. Annual average consumption from the EIA 2010 Annual Energy Outlook Early Release was seasonally adjusted using actual 2005/2006 consumption as reported by the EIA in Petroleum Marketing Monthly.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) The difference between the ethanol in Domestic Refinery Gasoline Production and Gasoline Consumption is the ethanol blended into the imported gasoline blendstocks.

(4) Totals represent finished gasoline produced from refinery CBOB, RBOB, and CARBOB as determined by *PRISM* simulations and include 10 Vol.% ethanol added to domestic refinery production. Gasoline blender production, based on blendstock sources other than from domestic refiners, is not included.

(5) Total U.S. gasoline consumption is based on the full year 2016 forecast contained in the EIA 2010 Annual Energy Outlook Early Release. PADD level allocations are based on annual 2005/2006 vehicle miles traveled as reported by the U.S. Department of Transportation. Grade allocations are based on 2005/2006 average annual share of sales as reported in the Petroleum Marketing Annual.

(6) Net supply requirements are from finished gasoline and gasoline blendstocks, excluding oxygenates, either from foreign imports or non-refinery supply.

TABLE 21A

Sensitivity Case 2 2016 Summer Regional Finished Gasoline Qualities[1,2]
At Refinery Gate (Before Ethanol is Added)

	TOTAL U.S.	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5
Domestic Production by Crude Oil Refiners[3]						
Total Pool						
RVP, psi	6.0	5.9	6.0	6.0	6.4	5.9
Olefins, Vol.%	8.9%	10.4%	10.0%	9.3%	10.5%	5.4%
Aromatics, Vol.%	30.9%	30.6%	31.6%	31.9%	29.1%	27.9%
Benzene, Vol.%	0.61%	0.71%	0.72%	0.55%	0.75%	0.57%
Sulfur, wppm	10.9	12.0	12.1	12.4	12.6	4.5
Lower Sulfur, Lower RVP Gasoline - C						
RVP, psi	6.3	6.4	6.2	6.2	6.4	6.3
Olefins, Vol.%	10.2%	10.1%	10.6%	10.2%	10.5%	8.5%
Aromatics, Vol.%	33.2%	37.5%	32.5%	33.4%	29.1%	33.2%
Benzene, Vol.%	0.67%	0.71%	0.83%	0.58%	0.75%	0.75%
Sulfur, wppm	11.8	10.8	12.2	12.5	12.6	6.7
Lower Sulfur, Lower RVP Gasoline - R						
RVP, psi	5.4	5.4	5.4	5.4	-	5.4
Olefins, Vol.%	7.9%	10.7%	8.3%	7.0%	-	4.6%
Aromatics, Vol.%	27.3%	22.8%	28.9%	27.8%	-	30.2%
Benzene, Vol.%	0.52%	0.70%	0.44%	0.48%	-	0.70%
Sulfur, wppm	12.2	13.4	12.0	12.3	-	7.6
CARBOB						
RVP, psi	5.8	-	-	-	-	5.8
Olefins, Vol.%	4.0%	-	-	-	-	4.0%
Aromatics, Vol.%	25.5%	-	-	-	-	25.5%
Benzene, Vol.%	0.49%	-	-	-	-	0.49%
Sulfur, wppm	3.4	-	-	-	-	3.4

NOTES:

(1) "Summer" is defined as April through September.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) *PRISM* simulation results.

TABLE 21B

Sensitivity Case 2 2016 Summer Regional Finished Gasoline Qualities[1,2]
(includes Ethanol)

	TOTAL U.S.	*PADD 1*	*PADD 2*	*PADD 3*	*PADD 4*	*PADD 5*
Domestic Production by Crude Oil Refiners[3]						
Total Pool						
RVP, psi	7.4	7.3	7.4	7.4	7.7	7.3
Olefins, Vol.%	8.0%	9.3%	9.0%	8.4%	9.5%	4.8%
Aromatics, Vol.%	27.8%	27.5%	28.4%	28.8%	26.2%	25.1%
Benzene, Vol.%	0.56%	0.64%	0.66%	0.50%	0.68%	0.52%
Sulfur, wppm	10.8	11.8	11.9	12.2	12.3	5.1
Lower Sulfur, Lower RVP Gasoline - C						
RVP, psi	7.6	7.7	7.6	7.6	7.7	7.7
Olefins, Vol.%	9.1%	9.1%	9.5%	9.1%	9.5%	7.6%
Aromatics, Vol.%	29.9%	33.7%	29.3%	30.1%	26.2%	29.9%
Benzene, Vol.%	0.61%	0.65%	0.75%	0.52%	0.68%	0.68%
Sulfur, wppm	11.7	10.8	11.9	12.2	12.3	7.0
Lower Sulfur, Lower RVP Gasoline - R						
RVP, psi	6.9	6.9	6.9	6.9	-	6.9
Olefins, Vol.%	7.1%	9.6%	7.5%	6.3%	-	4.1%
Aromatics, Vol.%	24.5%	20.5%	26.0%	25.0%	-	27.1%
Benzene, Vol.%	0.47%	0.64%	0.41%	0.44%	-	0.64%
Sulfur, wppm	12.0	13.0	11.8	12.0	-	7.9
CARBOB						
RVP, psi	7.2	-	-	-	-	7.2
Olefins, Vol.%	3.6%	-	-	-	-	3.6%
Aromatics, Vol.%	23.0%	-	-	-	-	23.0%
Benzene, Vol.%	0.45%	-	-	-	-	0.45%
Sulfur, wppm	4.1	-	-	-	-	4.1

NOTES:

(1) "Summer" is defined as April through September.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) *PRISM* simulation results.

TABLE 22

Sensitivity Case 2 2016 Summer Production[1,2]

(Thousands of Barrels Per Day - Including Ethanol)

	TOTAL U.S.	*PADD 1*	*PADD 2*	*PADD 3*	*PADD 4*	*PADD 5*
Domestic Production by Crude Oil Refiners[3]						
E85 Gasoline	65.4	0.4	64.7	0.1	0.0	0.2
Lower Sulfur, Lower RVP Gasoline - C	4,751	319	1,153	2,589	310	381
Lower Sulfur, Lower RVP Gasoline - R	1,653	284	421	909	-	39
CARB Gasoline	869	-	-	-	-	869
Jet Fuel	1,666	109	273	796	41	447
Distillates	4,251	285	960	2,311	177	518
Pentanes	437	40	78	225	6	88
Other[4]	4,135	434	756	2,153	41	751
TOTAL	**17,826**	**1,471**	**3,705**	**8,982**	**574**	**3,094**

NOTES:

(1) "Summer" is defined as April through September. Annual average consumption from the EIA 2010 Annual Energy Outlook Early Release was seasonally adjusted using actual 2005/2006 consumption as reported by the EIA in Petroleum Marketing Monthly.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) Totals represent finished gasoline produced from refinery CBOB, RBOB, and CARBOB as determined by *PRISM* simulations and include 10 Vol.% ethanol added to refinery production. Gasoline blender production, based on blendstock sources other than from domestic refiners, is not included.

(4) Includes LPG, residual fuel oil, aviation gasoline, petrochemical feedstocks, lubricants, waxes, asphalt, road oil, still gas, special naphthas, petroleum coke, and miscellaneous petroleum products.

TABLE 23

Sensitivity Case 3 2016 Summer Supply Balance[1,2]

(Thousands of Barrels Per Day - Including Ethanol)

	Ethanol[3]	*Hydrocarbon*	*TOTAL U.S.*	*PADD 1*	*PADD 2*	*PADD 3*	*PADD 4*	*PADD 5*
Domestic Refinery Gasoline Production[4]								
E85	48.4	17.0	65.4	0.4	64.7	0.1	0.0	0.2
Lower Sulfur, Lower RVP Gasoline - C	501.2	4,510	5,012	331	1,232	2,730	324	394
Lower Sulfur, Lower RVP Gasoline - R	166.3	1,496	1,663	284	409	931	-	39
CARB	87.7	790	877	-	-	-	-	877
TOTAL	**804**	**6,813**	**7,617**	**615**	**1,706**	**3,662**	**324**	**1,311**
Gasoline Consumption[5]								
E85	48.4	17.0	65.4	0.4	64.7	0.1	0.0	0.2
Lower Sulfur, Lower RVP Gasoline - C	627.0	5,643	6,270	2,132	2,080	1,172	369	517
Lower Sulfur, Lower RVP Gasoline - R	210.1	1,891	2,101	1,307	358	345	-	91
CARB	111.8	1,006	1,118	-	-	-	-	1,118
TOTAL	**997**	**8,558**	**9,555**	**3,440**	**2,503**	**1,517**	**369**	**1,726**
Domestic Refinery Over/(Under) Supply[6]								
E85		-	-	-	-	-	-	-
Lower Sulfur, Lower RVP Gasoline - C		(1,133)	(1,259)	(1,801)	(848)	1,558	(45)	(122)
Lower Sulfur, Lower RVP Gasoline - R		(395)	(439)	(1,024)	51	586	-	(53)
CARB		(216)	(241)	-	-	-	-	(241)
TOTAL		**(1,744)**	**(1,938)**	**(2,825)**	**(797)**	**2,144**	**(45)**	**(415)**

NOTES:

(1) "Summer" is defined as April through September. Annual average consumption from the EIA 2010 Annual Energy Outlook Early Release was seasonally adjusted using actual 2005/2006 consumption as reported by the EIA in Petroleum Marketing Monthly.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) The difference between the ethanol in Domestic Refinery Gasoline Production and Gasoline Consumption is the ethanol blended into the imported gasoline blendstocks.

(4) Totals represent finished gasoline produced from refinery CBOB, RBOB, and CARBOB as determined by *PRISM* simulations and include 10 Vol.% ethanol added to domestic refinery production. Gasoline blender production, based on blendstock sources other than from domestic refiners, is not included.

(5) Total U.S. gasoline consumption is based on the full year 2016 forecast contained in the EIA 2010 Annual Energy Outlook Early Release. PADD level allocations are based on annual 2005/2006 vehicle miles traveled as reported by the U.S. Department of Transportation. Grade allocations are based on 2005/2006 average annual share of sales as reported in the Petroleum Marketing Annual.

(6) Net supply requirements are from finished gasoline and gasoline blendstocks, excluding oxygenates, either from foreign imports or non-refinery supply.

TABLE 24A

Sensitivity Case 3 2016 Summer Regional Finished Gasoline Qualities[1,2]
At Refinery Gate (Before Ethanol is Added)

	TOTAL U.S.	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5
Domestic Production by Crude Oil Refiners[3]						
Total Pool						
RVP, psi	6.6	6.3	6.7	6.7	7.5	6.2
Olefins, Vol.%	9.6%	11.2%	9.8%	10.5%	10.1%	5.7%
Aromatics, Vol.%	29.7%	29.6%	30.1%	30.5%	27.9%	27.5%
Benzene, Vol.%	0.59%	0.69%	0.70%	0.53%	0.73%	0.56%
Sulfur, wppm	10.8	11.8	12.0	12.2	12.1	4.5
Lower Sulfur, Lower RVP Gasoline - C						
RVP, psi	7.1	7.1	7.1	7.1	7.5	7.4
Olefins, Vol.%	11.2%	11.5%	10.5%	11.8%	10.1%	10.1%
Aromatics, Vol.%	32.2%	36.9%	30.8%	33.1%	27.9%	30.2%
Benzene, Vol.%	0.63%	0.63%	0.80%	0.54%	0.73%	0.66%
Sulfur, wppm	11.8	10.2	12.5	12.4	12.1	6.8
Lower Sulfur, Lower RVP Gasoline - R						
RVP, psi	5.4	5.4	5.4	5.4	-	5.4
Olefins, Vol.%	7.6%	10.8%	7.8%	6.7%	-	4.6%
Aromatics, Vol.%	24.0%	21.1%	28.0%	22.9%	-	30.2%
Benzene, Vol.%	0.51%	0.77%	0.39%	0.48%	-	0.70%
Sulfur, wppm	11.6	13.8	10.4	11.7	-	7.6
CARBOB						
RVP, psi	5.8	-	-	-	-	5.8
Olefins, Vol.%	3.8%	-	-	-	-	3.8%
Aromatics, Vol.%	26.1%	-	-	-	-	26.1%
Benzene, Vol.%	0.51%	-	-	-	-	0.51%
Sulfur, wppm	3.4	-	-	-	-	3.4

NOTES:

(1) "Summer" is defined as April through September.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) *PRISM* simulation results.

TABLE 24B

Sensitivity Case 3 2016 Summer Regional Finished Gasoline Qualities[1,2] (includes Ethanol)

	TOTAL U.S.	*PADD 1*	*PADD 2*	*PADD 3*	*PADD 4*	*PADD 5*
Domestic Production by Crude Oil Refiners[3]						
Total Pool						
RVP, psi	7.9	7.7	8.0	7.9	8.7	7.6
Olefins, Vol.%	8.6%	10.1%	8.8%	9.5%	9.1%	5.1%
Aromatics, Vol.%	26.7%	26.6%	27.1%	27.4%	25.1%	24.7%
Benzene, Vol.%	0.54%	0.63%	0.63%	0.48%	0.66%	0.51%
Sulfur, wppm	10.7	11.6	11.8	12.0	11.9	5.1
Lower Sulfur, Lower RVP Gasoline - C						
RVP, psi	8.3	8.3	8.3	8.3	8.7	8.5
Olefins, Vol.%	10.1%	10.4%	9.4%	10.6%	9.1%	9.1%
Aromatics, Vol.%	29.0%	33.2%	27.7%	29.8%	25.1%	27.2%
Benzene, Vol.%	0.57%	0.57%	0.72%	0.49%	0.66%	0.60%
Sulfur, wppm	11.6	10.2	12.3	12.1	11.9	7.1
Lower Sulfur, Lower RVP Gasoline - R						
RVP, psi	6.9	6.9	6.9	6.9	-	6.9
Olefins, Vol.%	6.8%	9.7%	7.0%	6.0%	-	4.1%
Aromatics, Vol.%	21.6%	19.0%	25.2%	20.6%	-	27.1%
Benzene, Vol.%	0.47%	0.70%	0.36%	0.44%	-	0.64%
Sulfur, wppm	11.5	13.4	10.4	11.5	-	7.9
CARBOB						
RVP, psi	7.2	-	-	-	-	7.2
Olefins, Vol.%	3.4%	-	-	-	-	3.4%
Aromatics, Vol.%	23.5%	-	-	-	-	23.5%
Benzene, Vol.%	0.46%	-	-	-	-	0.46%
Sulfur, wppm	4.1	-	-	-	-	4.1

NOTES:

(1) "Summer" is defined as April through September.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) *PRISM* simulation results.

TABLE 25

Sensitivity Case 3 2016 Summer Production[1,2]

(Thousands of Barrels Per Day - Including Ethanol)

	TOTAL U.S.	*PADD 1*	*PADD 2*	*PADD 3*	*PADD 4*	*PADD 5*
Domestic Production by Crude Oil Refiners[3]						
E85 Gasoline	65.4	0.4	64.7	0.1	0.0	0.2
Lower Sulfur, Lower RVP Gasoline - C	5,012	331	1,232	2,730	324	394
Lower Sulfur, Lower RVP Gasoline - R	1,663	284	409	931	-	39
CARB Gasoline	877	-	-	-	-	877
Jet Fuel	1,667	109	273	796	41	448
Distillates	4,250	285	960	2,310	177	518
Pentanes	269	28	41	130	0	70
Other[4]	4,323	432	750	2,240	134	766
TOTAL	**18,125**	**1,469**	**3,729**	**9,138**	**676**	**3,114**

NOTES:

(1) "Summer" is defined as April through September. Annual average consumption from the EIA 2010 Annual Energy Outlook Early Release was seasonally adjusted using actual 2005/2006 consumption as reported by the EIA in Petroleum Marketing Monthly.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) Totals represent finished gasoline produced from refinery CBOB, RBOB, and CARBOB as determined by *PRISM* simulations and include 10 Vol.% ethanol added to refinery production. Gasoline blender production, based on blendstock sources other than from domestic refiners, is not included.

(4) Includes LPG, residual fuel oil, aviation gasoline, petrochemical feedstocks, lubricants, waxes, asphalt, road oil, still gas, special naphthas, petroleum coke, and miscellaneous petroleum products.

TABLE 26

Study Case vs. Base Case Summer 2016[1,2]

(Thousands of Barrels Per Day Unless Otherwise Stated)

	TOTAL U.S.	*PADD 1*	*PADD 2*	*PADD 3*	*PADD 4*	*PADD 5*
Crude Inputs						
Base Case	14,941	1,118	3,256	7,400	596	2,571
Study Case	14,511	1,118	3,111	7,293	596	2,393
Delta	**(430)**	**-**	**(145)**	**(107)**	**-**	**(178)**
Delta, %	**-3%**	**0%**	**-4%**	**-1%**	**0%**	**-7%**
Total Refinery Inputs						
Base Case	16,402	1,261	3,434	8,250	623	2,835
Study Case	15,864	1,262	3,257	8,077	610	2,657
Delta	**(538)**	**1**	**(177)**	**(172)**	**(13)**	**(177)**
Delta, %	**-3%**	**0%**	**-5%**	**-2%**	**-2%**	**-6%**
LSRBOB (excl. EtOH)[3]						
Base Case	6,567	609	1,741	3,519	310	389
Study Case	5,501	523	1,346	3,015	258	359
Delta	**(1,066)**	**(86)**	**(395)**	**(504)**	**(51)**	**(29)**
Delta, %	**-16%**	**-14%**	**-23%**	**-14%**	**-17%**	**-8%**
CARBOB (excl. EtOH)						
Base Case	868	-	-	-	-	868
Study Case	776	-	-	-	-	776
Delta	**(91)**	**-**	**-**	**-**	**-**	**(91)**
Delta, %	**-11%**					**-11%**
Distillates						
Base Case	5,733	410	1,156	3,012	211	944
Study Case	5,911	432	1,231	3,106	220	922
Delta	**178**	**22**	**75**	**95**	**9**	**(22)**
Delta, %	**3%**	**5%**	**6%**	**3%**	**4%**	**-2%**
Refinery Hydrogen Purchases[4]						
Base Case (MMSCFD)	1,629.7	20.1	36.5	1,326.7	0.8	245.5
Study Case (MMSCFD)	1,793.6	28.4	64.8	1,424.5	1.5	274.5
Delta (MMSCFD)[5]	**163.9**	**8.2**	**28.3**	**97.7**	**0.6**	**29.0**
Delta, %	**10%**	**41%**	**77%**	**7%**	**72%**	**12%**

NOTES:

(1) "Summer" is defined as April through September.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) LSRBOB is Lower Sulfur, Lower RVP Gasoline Blend for Oxygenate Blending. Base Case includes E85 hydrocarbon, CBOB and RBOB and the Study Case includes E85 hydrocarbon and LSRBOB.

(4) Refinery Hydrogen Purchases is the total hydrogen purchased by domestic refineries to produce fuels.

(5) Difference in reported delta values are due to rounding.

SOURCE: Baker & O'Brien *PRISM* simulations

TABLE 27

Sensitivity Case 1 vs. Base Case Summer 2016[1,2]

(Thousands of Barrels Per Day Unless Otherwise Stated)

	TOTAL U.S.	*PADD 1*	*PADD 2*	*PADD 3*	*PADD 4*	*PADD 5*
Crude Inputs						
Base Case	14,941	1,118	3,256	7,400	596	2,571
Sensitivity Case 1	14,328	1,118	3,046	7,140	596	2,428
Delta	**(613)**	**-**	**(210)**	**(260)**	**-**	**(143)**
Delta, %	**-4%**	**0%**	**-6%**	**-4%**	**0%**	**-6%**
Total Refinery Inputs						
Base Case	16,402	1,261	3,434	8,250	623	2,835
Sensitivity Case 1	15,679	1,266	3,191	7,918	612	2,693
Delta	**(723)**	**5**	**(243)**	**(332)**	**(11)**	**(142)**
Delta, %	**-4%**	**0%**	**-7%**	**-4%**	**-2%**	**-5%**
LSRBOB (excl. EtOH)[3]						
Base Case	6,567	609	1,741	3,519	310	389
Sensitivity Case 1	5,293	511	1,308	2,865	255	355
Delta	**(1,274)**	**(98)**	**(433)**	**(654)**	**(54)**	**(34)**
Delta, %	**-19%**	**-16%**	**-25%**	**-19%**	**-18%**	**-9%**
CARBOB (excl. EtOH)						
Base Case	868	-	-	-	-	868
Sensitivity Case 1	765	-	-	-	-	765
Delta	**(103)**	**-**	**-**	**-**	**-**	**(103)**
Delta, %	**-12%**					**-12%**
Distillates						
Base Case	5,733	410	1,156	3,012	211	944
Sensitivity Case 1	5,844	434	1,222	3,063	225	900
Delta	**111**	**23**	**66**	**51**	**14**	**(43)**
Delta, %	**2%**	**6%**	**6%**	**2%**	**7%**	**-5%**
Refinery Hydrogen Purchases[4]						
Base Case (MMSCFD)	1,618.4	20.1	36.5	1,315.4	0.8	245.5
Sensitivity Case 1 (MMSCFD)	1,911.2	46.3	93.5	1,469.3	1.5	300.5
Delta (MMSCFD)[5]	**292.8**	**26.2**	**57.0**	**153.9**	**0.6**	**55.0**
Delta, %	**18%**	**130%**	**156%**	**12%**	**74%**	**22%**

NOTES:

(1) "Summer" is defined as April through September.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) LSRBOB is Lower Sulfur, Lower RVP Gasoline Blend for Oxygenate Blending. Base Case includes E85 hydrocarbon, CBOB and RBOB and the Sensitivity Case 1 includes E85 hydrocarbon and LSRBOB.

(4) Refinery Hydrogen Purchases is the total hydrogen purchased by domestic refineries to produce fuels.

(5) Difference in reported delta values are due to rounding.

SOURCE: Baker & O'Brien *PRISM* simulations

TABLE 28

Sensitivity Case 2 vs. Base Case Summer 2016[1,2]

(Thousands of Barrels Per Day Unless Otherwise Stated)

	TOTAL U.S.	*PADD 1*	*PADD 2*	*PADD 3*	*PADD 4*	*PADD 5*
Crude Inputs						
Base Case	14,941	1,118	3,256	7,400	596	2,571
Sensitivity Case 2	14,511	1,118	3,111	7,293	596	2,393
Delta	**(430)**	**-**	**(145)**	**(107)**	**-**	**(178)**
Delta, %	**-3%**	**0%**	**-4%**	**-1%**	**0%**	**-7%**
Total Refinery Inputs						
Base Case	16,402	1,261	3,434	8,250	623	2,835
Sensitivity Case 2	15,860	1,260	3,255	8,075	612	2,658
Delta	**(543)**	**(1)**	**(178)**	**(175)**	**(11)**	**(177)**
Delta, %	**-3%**	**0%**	**-5%**	**-2%**	**-2%**	**-6%**
LSRBOB - C (excl. EtOH)[3]						
Base Case	4,941	286	1,430	2,558	310	357
Sensitivity Case 2	4,293	287	1,054	2,330	279	343
Delta	**(649)**	**1**	**(375)**	**(229)**	**(31)**	**(14)**
Delta, %	**-13%**	**0%**	**-26%**	**-9%**	**-10%**	**-4%**
LSRBOB - R (excl. EtOH)[4]						
Base Case	1,626	322	311	961		32
Sensitivity Case 2	1,487	255	379	818	-	35
Delta	**(138)**	**(67)**	**68**	**(143)**	**-**	**3**
Delta, %	**-9%**	**-21%**	**22%**	**-15%**	**-**	**11%**
CARBOB (excl. EtOH)						
Base Case	868	-	-	-	-	868
Sensitivity Case 2	782	-	-	-	-	782
Delta	**(86)**	**-**	**-**	**-**	**-**	**(86)**
Delta, %	**-10%**					**-10%**
Distillates						
Base Case	5,733	410	1,156	3,012	211	944
Sensitivity Case 2	5,917	394	1,233	3,107	218	966
Delta	**184**	**(17)**	**77**	**95**	**7**	**22**
Delta, %	**3%**	**-4%**	**7%**	**3%**	**3%**	**2%**
Refinery Hydrogen Purchases[5]						
Base Case (MMSCFD)	1,629.7	20.1	36.5	1,326.7	0.8	245.5
Sensitivity Case 2 (MMSCFD)	1,814.4	28.3	64.5	1,416.6	0.8	304.1
Delta (MMSCFD)[6]	**184.7**	**8.2**	**28.0**	**89.9**	**-**	**58.6**
Delta, %	**11%**	**41%**	**77%**	**7%**	**0%**	**24%**

NOTES:

(1) "Summer" is defined as April through September.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) LSRBOB - C is Lower Sulfur, Lower RVP Gasoline Blend for Oxygenate Blending. Base Case includes E85 hydrocarbon, CBOB and the Sensitivity Case 2 includes E85 hydrocarbon and LSRBOB - C.

(4) LSRBOB - R is Lower Sulfur, Lower RVP Gasoline Blend for Oxygenate Blending. Base Case includes RBOB and the Sensitivity Case 2 includes

(5) Refinery Hydrogen Purchases is the total hydrogen purchased by domestic refineries to produce fuels.

(6) Difference in reported delta values are due to rounding.

SOURCE: Baker & O'Brien *PRISM* simulations

TABLE 29

Sensitivity Case 3 vs. Base Case Summer 2016[1,2]

(Thousands of Barrels Per Day Unless Otherwise Stated)

	TOTAL U.S.	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5
Crude Inputs						
Base Case	14,941	1,118	3,256	7,400	596	2,571
Sensitivity Case 3	14,511	1,118	3,111	7,293	596	2,393
Delta	**(430)**	**-**	**(145)**	**(107)**	**-**	**(178)**
Delta, %	**-3%**	**0%**	**-4%**	**-1%**	**0%**	**-7%**
Total Refinery Inputs						
Base Case	16,402	1,261	3,434	8,250	623	2,835
Sensitivity Case 3	15,923	1,258	3,271	8,119	617	2,658
Delta	**(479)**	**(3)**	**(163)**	**(131)**	**(5)**	**(177)**
Delta, %	**-3%**	**0%**	**-5%**	**-2%**	**-1%**	**-6%**
LSRBOB - C (excl. EtOH)[3]						
Base Case	4,941	286	1,430	2,558	310	357
Sensitivity Case 3	4,527	298	1,126	2,457	291	355
Delta	**(414)**	**12**	**(304)**	**(101)**	**(18)**	**(2)**
Delta, %	**-8%**	**4%**	**-21%**	**-4%**	**-6%**	**-1%**
LSRBOB - R (excl. EtOH)[4]						
Base Case	1,626	322	311	961		32
Sensitivity Case 3	1,496	255	368	838		35
Delta	**(129)**	**(67)**	**57**	**(123)**	**-**	**3**
Delta, %	**-8%**	**-21%**	**18%**	**-13%**	**-**	**11%**
CARBOB (excl. EtOH)						
Base Case	868	-	-	-	-	868
Sensitivity Case 3	790	-	-	-	-	790
Delta	**(78)**	**-**	**-**	**-**	**-**	**(78)**
Delta, %	**-9%**					**-9%**
Distillates						
Base Case	5,733	410	1,156	3,012	211	944
Sensitivity Case 3	5,916	394	1,233	3,106	218	966
Delta	**183**	**(17)**	**77**	**95**	**7**	**23**
Delta, %	**3%**	**-4%**	**7%**	**3%**	**3%**	**2%**
Refinery Hydrogen Purchases[5]						
Base Case (MMSCFD)	1,629.7	20.1	36.5	1,326.7	0.8	245.5
Sensitivity Case 3 (MMSCFD)	1,814.6	28.3	64.5	1,416.5	0.8	304.4
Delta (MMSCFD)[6]	**184.9**	**8.2**	**28.0**	**89.8**	**-**	**58.9**
Delta, %	**11%**	**41%**	**77%**	**7%**	**0%**	**24%**

NOTES:

(1) "Summer" is defined as April through September.

(2) As described in the main body of the report entitled "Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline"

(3) LSRBOB - C is Lower Sulfur, Lower RVP Gasoline Blend for Oxygenate Blending. Base Case includes E85 hydrocarbon, CBOB and the Sensitivity Case 3 includes E85 hydrocarbon and LSRBOB - C.

(4) LSRBOB - R is Lower Sulfur, Lower RVP Gasoline Blend for Oxygenate Blending. Base Case includes RBOB and the Sensitivity Case 3 includes

(5) Refinery Hydrogen Purchases is the total hydrogen purchased by domestic refineries to produce fuels.

(6) Difference in reported delta values are due to rounding.

SOURCE: Baker & O'Brien *PRISM* simulations