

Future Gasoline Octane Scenarios

Prepared for



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Administration



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1. NOTICE

This report was prepared by Baker & O'Brien, Inc. (Baker & O'Brien) using its own models and analysis. The opinions and findings in this report are based upon Baker & O'Brien's experience, expertise, skill, research, analysis, and related work to date. Forecasts and projections contained in this report represent Baker & O'Brien's best judgment utilizing its skill and expertise and are inherently uncertain due to the potential impact of factors or future events that are unforeseeable at this time or beyond Baker & O'Brien's control. In the event that additional information should subsequently become available that is material to the conclusions presented herein, Baker & O'Brien reserves the right to supplement or amend this report. Nothing in this report should be construed as a recommendation for or against implementing any policies and regulations. Baker & O'Brien expressly disclaims all liability for the use, disclosure, reproduction, or distribution of this report by or to any third party.

2. EXECUTIVE SUMMARY

Since 2012, the average retail price differential between regular and premium gasoline in the United States increased from approximately 0.20 dollars per gallon (\$/gal) – 0.30 \$/gal to 0.53 \$/gal in 2017. The differential has roughly doubled in Petroleum Administration for Defense Districts (PADDs) 1, 2, 3, and 4 from the range of 0.20 \$/gal - 0.30 \$/gal to 0.50 \$/gal - 0.55 \$/gal, with a more modest increase in PADD 5, from approximately 0.25 \$/gal to 0.35 \$/gal. The United States (U.S.) Energy Information Administration (EIA) retained Baker & O'Brien, Inc. (Baker & O'Brien) to analyze the factors and conditions leading to the increased differentials and to study a future scenario with increased octane requirements. A separate Baker & O'Brien report (Phase 1 Report) addresses the retrospective analysis. This report documents Baker & O'Brien's analysis of the future scenario at two points in time: 2022 and 2027. The specific issue addressed in this report is whether the domestic refining industry will be able to meet higher octane gasoline requirements.

2.1 ANALYTICAL BASIS

This study assumes that starting with model year 2023 all U.S. "light duty vehicles" and "commercial light trucks"¹ (collectively, "LDVT") will require 95 Research Octane Number (RON) gasoline. The study assumes that 95 RON gasoline will be required at the refinery level by January 1, 2022, in anticipation of the vehicle model changeover during calendar year 2022. It is further assumed that 95 RON gasoline will completely replace the current premium gasoline grade. Consumption of 95 RON gasoline will grow as a percentage of total gasoline over time as the domestic vehicle fleet turns over. Except for octane and the Tier 3² sulfur regulations, all existing regional gasoline specifications (e.g., Reid Vapor Pressure) were assumed to remain unchanged. Essentially all domestic gasoline consumed in the 2022 and 2027 cases is assumed to contain 10 percent (%) ethanol (E10).

¹ As defined in the 2018 EIA AEO, light duty vehicles are those weighing less than 8,501 pounds, and commercial light trucks are those with 8,501 to 10,000 pounds gross vehicle weight rating.

² The Tier 3 gasoline sulfur program sets new vehicle emissions standards and lowers the gasoline sulfur content to a maximum company annual average of 10 ppm beginning in 2017 for most refiners and by 2020 for all refiners.

Gasoline consumption and production changes were based on the 2018 EIA Annual Energy Outlook Reference Case (2018 AEO). The 2018 AEO forecast includes significant reductions in gasoline consumption through 2027. The conclusions reached in this study might have been different with an alternate consumption forecast.

Baker & O'Brien's *PRISM™* estimates of actual 2016 refinery operations were used as a starting point for the analysis of refinery operations.³ Refinery expansions and modifications currently underway or required under current regulations (Tier 3) were incorporated in the 2022 and 2027 cases. No additional expansions or modifications were included. The crude slate for each refinery was kept constant, unless the refinery is undergoing modifications. No changes in product pipeline capacity, direction, or service were included.

The 2018 AEO forecast includes significantly reduced gasoline consumption but relatively flat distillate consumption. Except in PADD 3, refinery operations were modified to decrease gasoline while maintaining overall PADD distillate production. It was also assumed that net gasoline exports from PADD 3 could be increased as needed to maintain operating rates. This methodology is optimistic in regard to the domestic refining industry and is directionally consistent with the utilization rates in the 2018 AEO. Actual refinery operations, domestic gasoline distribution patterns, and product exports will be determined by market forces and could be significantly different.

As discussed in the Phase 1 Report, on average, domestic refinery reformer capacity utilization and severity were well below full potential in 2016.⁴ This underutilized capacity represents a significant source of potential octane. Alkylation units represent another source of octane and all refinery alkylation unit throughput was maximized in all cases, consistent with the Phase 1 analysis. Reformer throughput and severity were increased or decreased within normal operating ranges as needed to meet octane requirements.

³ *PRISM™* is a trademark of Baker & O'Brien, Inc. All rights reserved. Baker & O'Brien's *PRISM* estimates of actual operations are calibrated quarterly to match EIA published operating data at a refining district level and other published data at a company or individual refinery level.

⁴ Reformers and reformer severity are discussed in detail in the Phase 1 Report.

2.2 RESULTS AND CONCLUSIONS

Introduction of the new 95 RON grade in 2022 reduces octane requirements because it replaces premium grades with up to 98 RON. As a result, existing domestic refineries should have no problem meeting the 2022 requirements based on the assumptions in this study. The reductions in gasoline consumption do result in significant changes in gasoline movements between PADDs, but the existing product distribution system should be able to handle these changes. Based on the optimistic assumptions about refinery operating rates, the 2022 case includes a 417,000 barrels per day (b/d) increase in U.S. net gasoline exports, from 144,000 b/d in 2016 to 561,000 b/d in 2022.

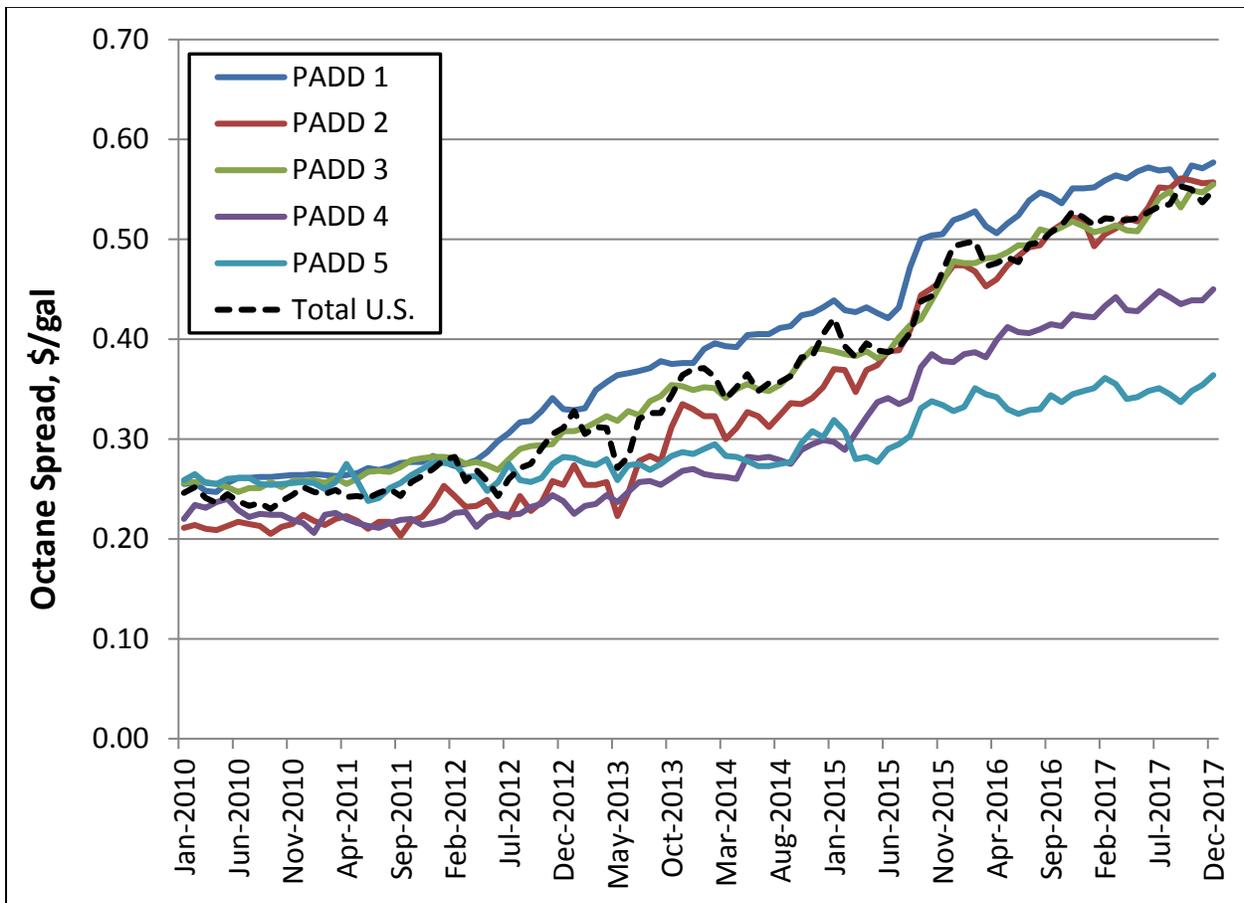
After 2022, increasing 95 RON consumption and increased exports of non-blendstocks for oxygenate blending (BOB) gasoline combine to significantly increase the average octane of refinery produced gasoline and reformer severity through 2027. By 2027, the 2018 AEO forecast 18.1% reduction in gasoline consumption versus 2016 causes significant cuts in PADDs 1, 2, 4, and 5 gasoline production. The production cuts caused reduced refinery utilization and refinery shutdowns in PADDs 1, 4, and 5. Average reformer severity increased from 90.8 RON in 2016 to 93.0 RON in 2027, but this is well within the range of normal operations. Existing refineries appear to be able to meet the increased 2027 octane requirements with minor operational adjustments. No industry-wide capital intensive projects would be needed to meet the 2027 requirements.

The reductions in gasoline consumption assumed in the 2027 case caused a further shift in PADD-to-PADD gasoline transfers. Based on the operating rate assumptions, U.S. net gasoline exports reached 1.4 million b/d in 2027, a 724% increase over 2016. If market conditions are not conducive to this increase, additional refinery shutdowns would likely occur.

3. INTRODUCTION

Since 2012, the retail price difference between regular grade gasoline, typically 87 Anti-Knock Index (AKI), and premium grade gasoline, typically 91 AKI to 93 AKI, has steadily increased in all Petroleum Administration for Defense Districts (PADDs) (Figure 1). For the entire United States during 2017, the average retail price differential between regular and premium gasoline (the “PRdiff”) averaged 0.53 dollars per gallon (\$/gal). In PADDs 1, 2, 3, and 4, the current differential is approximately double what it was in 2010 and 2011 (0.50 \$/gal - 0.55 \$/gal versus 0.20 \$/gal - 0.30 \$/gal). The differential has increased at a slower rate in PADD 5 (from approximately 0.25 \$/gal to 0.35 \$/gal).

FIGURE 1
PREMIUM TO REGULAR RETAIL PRICE DIFFERENTIAL



Source: U.S. Energy Information Administration

The United States (U.S.) Energy Information Administration (EIA) retained Baker & O'Brien, Inc. (Baker & O'Brien) to analyze the causal factors and conditions leading to increased PRdiffs in this decade and to analyze a future scenario, when a higher percentage of vehicles may require premium gasoline. The first phase of the project examined the period 2010 through 2016. Baker & O'Brien produced a separate report (Phase 1 Report) describing the first phase analysis and included a discussion of the following factors and conditions:

- Gasoline properties and specifications
- Gasoline consumption and octane requirements
- Production and supply
- Pricing differentials at the spot, rack, and retail levels

This report assesses the ability of the U.S. refining industry to meet octane requirements in the years 2022 and 2027, under a set of assumptions agreed to by EIA and Baker & O'Brien and discusses any subsequent impacts to the PRdiff due to the operational changes.

Baker & O'Brien made extensive use of its *PRISM*[™] Refining Industry Analysis modeling system in the performance of this study. The *PRISM* model is based on publicly-available information and Baker & O'Brien's industry experience and knowledge. No proprietary or confidential refining company information is solicited or included in the *PRISM* modeling results. The results are estimates and actual outcomes could vary.

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4. ANALYTICAL BASIS

To meet the future fuel economy standards,⁵ automobile manufacturers are expected to modify engine design, primarily by decreasing the engine size and increasing compression ratios. As compression ratios increase, so must the gasoline octane.⁶ Multiple parties have proposed a new 95 research octane number (RON) gasoline grade as the standard on which future engine designs will be based.^{7,8} 95 RON is the primary gasoline grade in Europe and other parts of the world.

This study assumes that starting with model year 2023 all U.S. “light duty vehicles” and “commercial light trucks”⁹ (collectively, “LDVT”) require 95 RON gasoline. The study assumes that 95 RON gasoline will be required at the refinery level by January 1, 2022, in anticipation of the model changeover during calendar year 2022. It is further assumed that 95 RON gasoline completely replaces the current premium gasoline grade. Consumption of 95 RON gasoline grows as a percentage of total gasoline over time as the domestic vehicle fleet turns over.

The 2018 AEO implies growing gasoline exports, and these are reflected in this analysis. This study assumes that gasoline exports will be non-oxygenated finished gasoline (not blendstocks for oxygenate blending [BOB]) and the ratio of 95 RON to 87 AKI regular gasoline will be the same as in domestic gasoline.

4.1 OCTANE SPECIFICATIONS

Octane rating measures a fuel’s ability to withstand compression without pre-igniting. In a gasoline engine, the piston moving upward in each cylinder compresses a fuel-air mixture. The mixture temperature increases with increasing compression. This combination of heat and

⁵ A discussion of CAFÉ standards is included in the Phase 1 Report, Section 4.4, p. 20.

⁶ Phase 1 Report, Section 4.4.1, pp. 21-22.

⁷ <http://www.autonews.com/article/20150805/OEM11/150809918/epa-studies-potential-benefits-of-higher-octane-gasoline>

⁸ <http://www.autonews.com/article/20180417/BLOG06/180419780/auto-industry-lobbies-for-95-octane-as-new-regular>.

⁹ As defined in the 2018 EIA AEO, light duty vehicles are those weighing less than 8,501 pounds, and commercial light trucks are those with 8,501 to 10,000 pounds gross vehicle weight rating.

pressure can cause the mixture to ignite (in the cylinder) before the spark plug fires, while the piston is in the upward stroke, resulting in the characteristic knocking or pinging sound and can lead to engine damage. Increasing compression ratios (the ratio of the maximum volume of a cylinder to its minimum volume) is an important means of improving engine efficiency and performance. As the compression ratio increases, the tendency of gasoline to pre-ignite also increases. Engines with higher compression ratios may require gasolines with higher octane ratings. Engine manufacturers specify the Octane Number Requirement (ONR) of each engine based on engine design factors and in-use conditions.

Two different methods are used to measure octane ratings. The RON method tests fuel at low engine loads by comparing it under variable compression ratios to mixtures of the reference fuels isooctane (100 RON) and normal heptane (0 RON). In most of the world, the RON is what is posted on the retail station pump. The second method, the Motor Octane Number (MON), is similar to RON testing but at a higher engine load. The arithmetic average of RON and MON (RON plus MON divided by two; $(R+M)/2$) is known as the AKI. The AKI is what is currently posted at retail station pumps in North America.

The 95 RON grade considered in this study has an AKI rating of between 90 and 91. In much of the country, premium gasoline currently has RON values above 95 (e.g., 93 AKI has a RON of 97 to 98). It was assumed that 95 RON gasoline meets the requirements of all “premium required” and “premium recommended” vehicles produced prior to model year 2023, and the 95 RON grade will not have a MON or AKI specification.

4.2 FUTURE OCTANE REQUIREMENTS

In the 2022 case, 95 RON (premium) gasoline consumption is assumed to be 12 percent (%) of total finished gasoline, similar to the 2016 Base Case. The 2027 case assumes premium gasoline sales increase in proportion to the increase in 95 RON-required vehicles based on the following:

1. 2022 premium-required vehicles account for 10% of light-duty vehicle and 0% of commercial light trucks, equivalent to 2016 levels. Similar to 2016, premium gasoline sales account for 12% of gasoline sales, exceeding the proportion of premium-required vehicles.
2. All new LDVT sold starting in model year 2023 require 95 RON. Premium-required vehicles already in service in 2022 consume 95 RON going forward.

3. Annual additions of 95 RON LDVT are based on the “*light-duty vehicle sales*” of gasoline and gasoline hybrids in Light-Duty Vehicle Sales by Technology Type (2018 AEO Reference Case Table 39) and “*fleet commercial light truck sales*” Transportation Fleet Car and Truck Sales by Type and Technology (2018 AEO Reference Case Table 45).
4. The additional 95 RON gasoline consumed each year by new vehicles is determined by the new vehicles sales multiplied by the LDVT energy efficiency indicators (mpg) in Transportation Sector Key Indicators and Delivered Energy Consumption (2018 AEO Reference Case Table 7).
5. The proportion of premium gasoline sales continues to exceed the level of premium-required vehicles.
6. Based on the above, 95 RON gasoline comprises 29.0% of total gasoline consumption in 2027.

4.3 OTHER GASOLINE SPECIFICATIONS

Except for octane and the Tier 3¹⁰ sulfur regulations, all existing regional gasoline specifications (e.g., Reid Vapor Pressure) were assumed to remain unchanged. Essentially all domestic gasoline consumed in the 2022 and 2027 cases is assumed to contain 10% ethanol (E10).

4.4 GASOLINE CONSUMPTION

Gasoline consumption and production changes were based on the 2018 AEO. For the PADD-by-PADD consumption forecast, the 2018 AEO total U.S. gasoline “product supplied”¹¹ was prorated based on actual 2016 consumption. Ethanol, as a percentage of total gasoline consumed, was assumed to be 10 volume percent (Vol.%) in all PADDs.

Relative to 2016, the 2018 AEO includes a 6.4% drop in gasoline consumption by 2022 and an 18.1% decrease by 2027 ([Table 1](#)). The 2018 AEO also includes large increases in gasoline exports. This study assumes the 2018 AEO scenario. Alternative assumptions about future gasoline consumption and exports could result in significantly different results than those in this report.

¹⁰ The Tier 3 gasoline sulfur program sets new vehicle emissions standards and lowers the gasoline sulfur content to a maximum company annual average of 10 ppm beginning in 2017 for most refiners and by 2020 for all refiners.

¹¹ [Table 1](#).

TABLE 1
GASOLINE CONSUMPTION (INCLUDES ETHANOL)¹²

	2016	2022	2027
	Mb/d	Mb/d	Mb/d
PADD 1	3,244	3,036	2,657
PADD 2	2,607	2,492	2,181
PADD 3	1,525	1,377	1,205
PADD 4	326	305	268
PADD 5	1,612	1,510	1,321
Total	9,314	8,720	7,631

4.5 GASOLINE PRODUCTION AND DISTRIBUTION

Baker & O'Brien's *PRISM* estimates of actual 2016 refinery operations were used as a starting point for the analysis.¹³ Refinery expansions and modifications currently underway or required under current regulations (Tier 3) were incorporated in the 2022 and 2027 cases. No additional expansions or modifications were included. The crude slate for each refinery was kept constant, unless the refinery is undergoing modifications. No changes in product pipeline capacity, direction, or service were included. Net imports of Canadian gasoline were held constant at 147,000 b/d. Net exports of gasoline from PADD 5 were also held constant at 17,000 b/d.

The 2018 AEO forecast includes significantly reduced gasoline consumption in 2022 and 2027 but relatively flat distillate consumption. Except in PADD 3, refinery operations were modified to decrease gasoline while maintaining overall PADD distillate production. Adjustments included changing cut-points across the refinery and conversion in hydrocrackers and fluid catalytic crackers. PADD-to-PADD transfers were adjusted to the extent possible with the existing pipeline infrastructure to maintain 2016 refinery operating rates. It was also assumed that net gasoline exports from PADD 3 could be increased as needed to maintain operating rates.

¹² Mb/d = thousand barrels per day.

¹³ Baker & O'Brien's *PRISM* estimates of actual operations are calibrated quarterly to match EIA published operating data at a refining district level and other published data at a company or individual refinery level.

If these changes in refinery operations and distribution patterns were insufficient to bring a PADD into gasoline balance, cuts in refinery throughput were implemented. If these cuts dropped the PADD average crude distillation capacity utilization below 80%, refinery (or partial refinery) shutdowns were implemented to the extent needed to maintain 80% utilization.

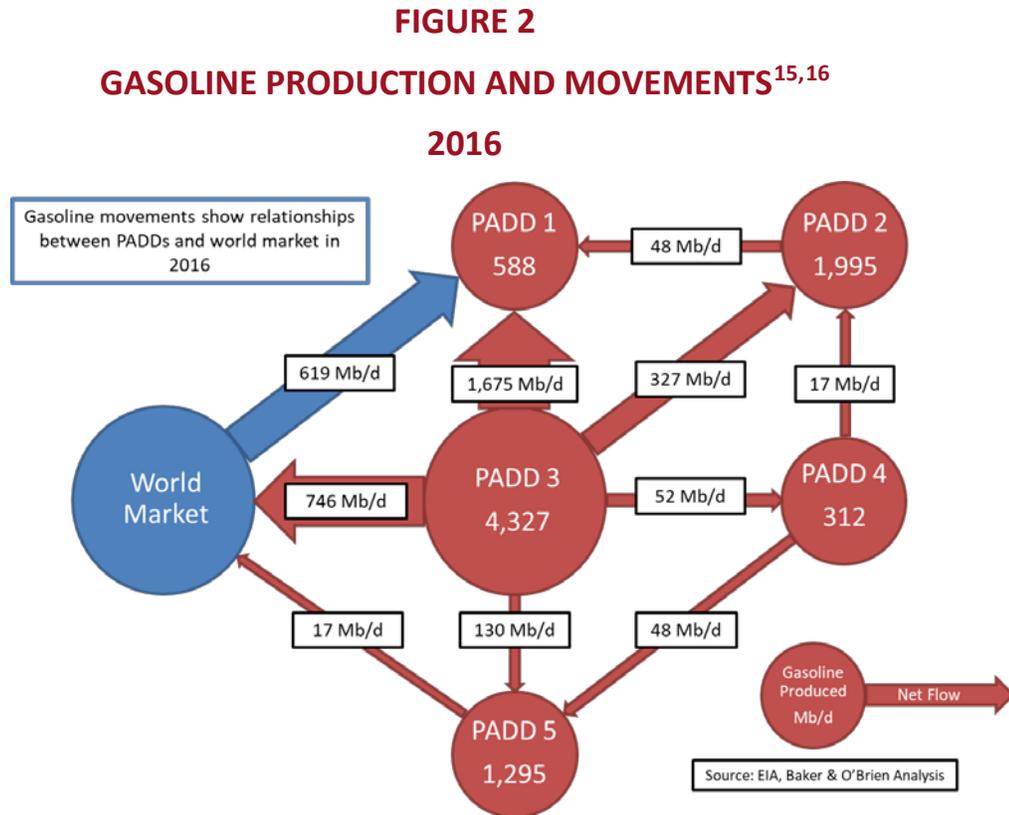
This methodology is optimistic in regards to the domestic refining industry and is directionally consistent with the utilization rates in the 2018 AEO. Actual refinery operations, domestic gasoline distribution patterns, and product exports will be determined by market forces and could be significantly different.

As discussed in the Phase 1 Report, on average, domestic refinery reformer capacity utilization and severity were well below full potential in 2016.¹⁴ This underutilized capacity represents a significant source of potential octane. Alkylation units represent another source of octane and all refinery alkylation unit throughput was maximized in all cases, consistent with the Phase 1 analysis. The Phase 1 Report mentions potential standalone alkylation units, but none are assumed in this analysis. Two new refinery alkylation units have been announced and included in this study. Reformer throughput and severity were increased or decreased within normal operating ranges as needed to meet octane requirements.

¹⁴ Reformers and reformer severity are discussed in detail in the Phase 1 Report.

5. RESULTS

Refining industry projections for 2022 and 2027 were built up, refinery by refinery, using Baker & O'Brien's *PRISM* modeling system and the methodology discussed in the preceding section. The projections are compared to 2016 actual results. For comparison, 2016 gasoline production and movements are shown below.



5.1 2022 CASE

The 2022 case required no significant changes in refinery configuration or throughput, and gasoline production remains near 2016 levels in all PADDs except PADD 5. The national

¹⁵ The PADD 3 to PADD 2 transfers shown here include 214,000 b/d of gasoline that moves through PADD 1 on its way to PADD 2. The EIA Petroleum Supply Monthly and Petroleum Supply Annual reports show this volume as both a PADD 3 to PADD 1 transfer and a PADD 1 to PADD 2 transfer.

¹⁶ Production and movement volumes do not include ethanol

average gasoline octane dropped slightly (0.2 RON) due to the premium gasoline specification change to 95 RON from 91 AKI - 93 AKI (95 RON - 98 RON). As mentioned above, premium gasoline consumption as a percentage of total gasoline was the same. Full implementation of Tier 3 sulfur limits had a negative RON impact.

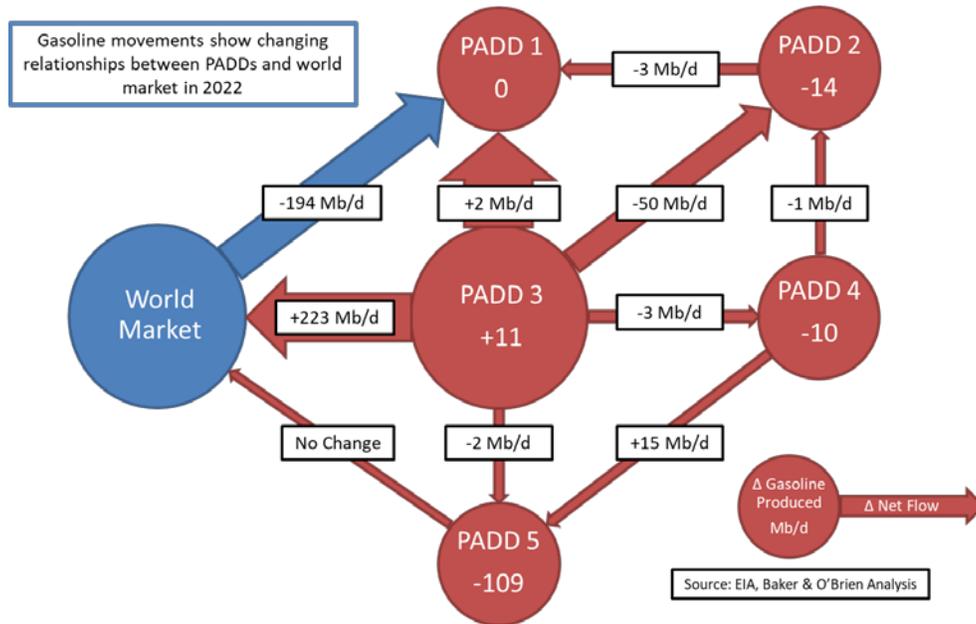
The Phase 1 Report discussed the concept of an octane-barrel (RON-barrel) as another way of measuring octane requirements. The combination of reduced gasoline volumes and a slight decrease in octane requirements resulted in just under a 2% decline in RON-barrel requirements (**Table 2**). Even with the negative impact of Tier 3, the 2022 octane requirements posed no significant challenges to domestic refineries.

TABLE 2
GASOLINE PRODUCTION AND RON-BARREL REQUIREMENTS
2016 AND 2022

Gasoline Production (includes ethanol)	2016		2022		Change	
	Mb/d	RON-Mb/d	Mb/d	RON-Mb/d	Mb/d	RON-Mb/d
PADD 1	653	60,400	653	60,253	0	(147)
PADD 2	2,214	203,767	2,202	202,529	(12)	(1,238)
PADD 3	4,713	433,813	4,704	432,127	(9)	(1,685)
PADD 4	345	31,455	335	30,548	(10)	(906)
PADD 5	1,434	132,352	1,313	121,060	(121)	(11,292)
Total	9,360	861,786	9,207	846,517	(153)	(15,270)

The 2022 case produced several significant shifts in gasoline movements (**Figure 3**). PADD 3 transfers to PADD 2 decreased from 327,000 b/d in 2016 to 277,000 b/d in 2022. PADD 3 net gasoline exports increased from 746,000 b/d to 969,000 b/d. Net PADD 1 gasoline imports fell from 619,000 b/d to 425,000 b/d. The combined impact was a 417,000 b/d increase in U.S. net gasoline exports, from 144,000 b/d in 2016 to 561,000 b/d in 2022.

FIGURE 3
CHANGE IN GASOLINE PRODUCTION AND MOVEMENTS¹⁷
2022 VERSUS 2016



5.2 2027 CASE

Continuing declines in gasoline consumption and production through 2027 resulted in refinery shutdowns in PADDs 1, 4, and 5 based on the methodology discussed in Section 4.5. Operational adjustments in the remaining refineries maintained distillate production and further reduced gasoline production. Gasoline production decreased in all PADDs.

Increased exports of non-BOB gasoline and increased consumption of 95 RON gasoline resulted in a 0.6 RON increase in the combined gasoline pool, the largest cumulative change for any five-year period since 2000. On an octane-barrel basis, gasoline production's continuing decline more than offset the octane increase, and total RON-barrel requirement in 2027 is lower than 2016 (Table 3).

¹⁷ Production and movement volumes do not include ethanol

TABLE 3
GASOLINE PRODUCTION AND RON-BARREL REQUIREMENTS
2016 AND 2027

Gasoline Production (includes ethanol)	2016		2027		Change	
	Mb/d	RON-Mb/d	Mb/d	RON-Mb/d	Mb/d	RON-Mb/d
PADD 1	653	60,400	492	45,627.9	(161)	(14,772)
PADD 2	2,214	203,767	2,059	190,909.2	(156)	(12,858)
PADD 3	4,713	433,813	4,640	428,686.3	(74)	(5,127)
PADD 4	345	31,455	299	27,399.9	(46)	(4,055)
PADD 5	1,434	132,352	1,124	103,946.3	(310)	(28,405)
Total	9,360	861,786	8,613	796,570	(746)	(65,217)

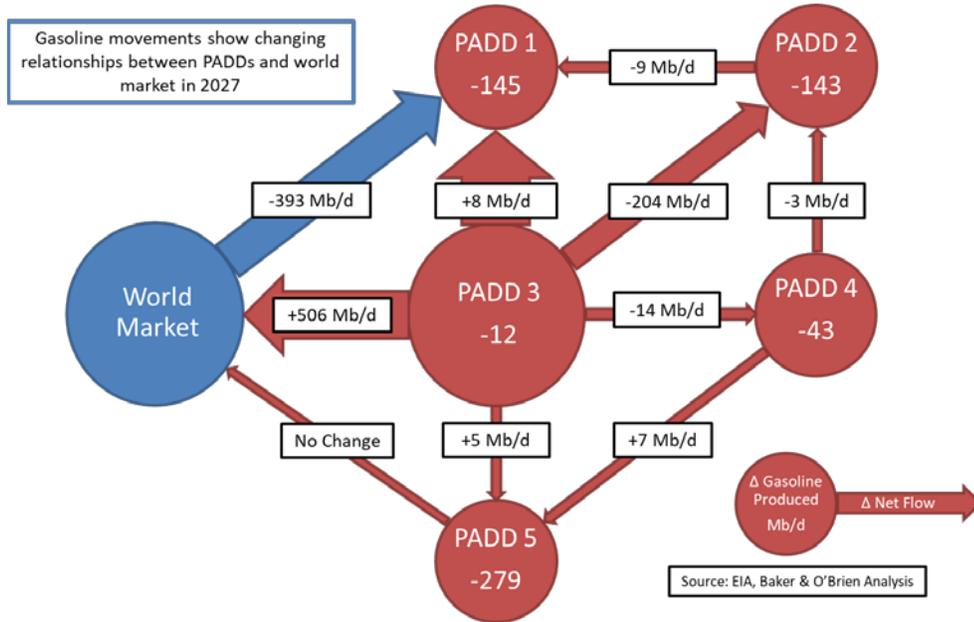
Even with a drop in octane-barrel requirements, the increase in average pool octane requires increases in reformer severity. The required increases remain well within normal operating ranges and should not pose a problem for refiners. The average 2027 reformer severity is 2.2 RON higher than 2016 (Table 4). This scenario does not include any impacts of stand-alone alkylation capacity additions or unannounced refinery projects.

TABLE 4
REFORMER SEVERITY (RON)
2016, 2022, AND 2027

	2016	2022	2027
PADD 1	88.1	87.3	90.7
PADD 2	90.7	89.8	92.1
PADD 3	91.6	91.7	94.3
PADD 4	87.6	87.4	90.0
PADD 5	90.0	89.5	90.6
U.S. Average	90.8	90.5	93.0

The changes in gasoline movements in the 2022 case were magnified in the 2027 case. PADD 3 transfers to PADD 2 dropped from 327,000 b/d in 2016 to 123,000 b/d in 2027. PADD 3 net gasoline exports increased from 746,000 b/d in 2016 to 1,252,000 b/d in 2027. Net PADD 1 gasoline imports fell from 619,000 b/d in 2016 to 226,000 b/d in 2027. The U.S. net gasoline exports saw a combined increase of 899,000 b/d from 144,000 b/d in 2016 to 1,043,000 b/d in 2027. Market conditions may not allow this increase, and additional refinery shutdowns may occur.

FIGURE 4
CHANGE IN GASOLINE PRODUCTION AND MOVEMENTS¹⁸
2027 VERSUS 2016

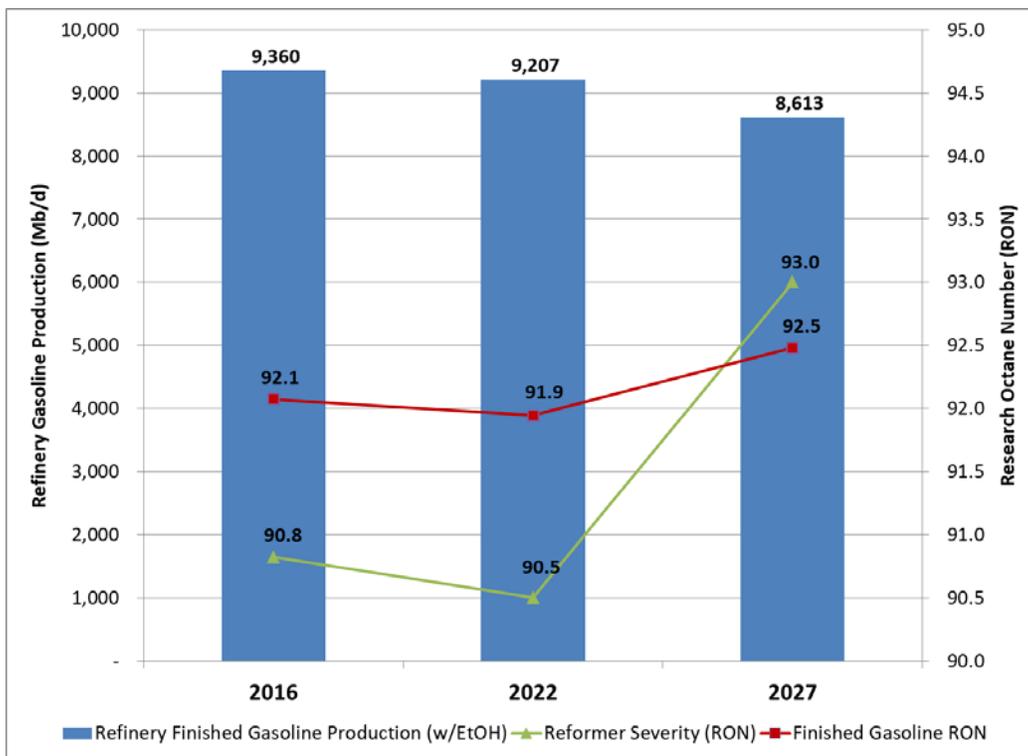


¹⁸ Production and movement volumes do not include ethanol

6. CONCLUSIONS

Introduction of the new 95 RON grade in 2022 reduces octane requirements because it replaces premium grades with up to 98 RON. After 2022, increasing 95 RON consumption and increased exports of non-BOB gasoline combine to increase the average octane of refinery produced gasoline and reformer severity through 2027 (Figure 5).

FIGURE 5
REFINERY GASOLINE PRODUCTION AND OCTANE REQUIREMENTS



From 2022 through 2027, the average gasoline pool RON increases by 0.6 RON, the highest cumulative change over any period of time since 2000. However, the continued decrease in gasoline production and consumption offsets the octane increase, and total octane-barrel demand in 2027 is lower than the 2016 starting point (Table 3, Section 5.2).

By 2027, the 2018 AEO forecast reduction in gasoline consumption causes significant cuts in PADDs 1, 2, 4, and 5 gasoline production relative to 2016. The production cuts are projected to be accomplished through a combination of reductions in refinery unit utilization and refinery

shutdowns in PADDs 1, 4, and 5. There could be additional refinery shutdowns if the forecast consumption decline occurs and market conditions are not conducive to a dramatic increase in net gasoline exports.

Reformer capacity and throughput decrease due to refinery shutdowns and reduced refinery crude oil throughput. As total gasoline and total RON-barrel demand both significantly decrease in the 2016-2027 period, the relative octane contribution to the gasoline pool from reformers increases (**Table 5**), along with the required Reformer Severity (**Table 4**, Section 5.2).

TABLE 5
REFORMATE OCTANE-BARRELS CONTRIBUTION TO GASOLINE POOL

	2016	2022	2027	<i>Cumulative % Increase, 2016-2027</i>
	% of Total	% of Total	% of Total	
PADD 1	27.0%	26.8%	27.4%	1.7%
PADD 2	26.8%	26.8%	27.3%	1.7%
PADD 3	29.4%	29.5%	30.5%	3.7%
PADD 4	25.0%	24.1%	23.6%	-5.5%
PADD 5	24.6%	24.9%	25.3%	2.7%
Total	27.7%	27.8%	28.6%	3.3%

The required increase in reformer severity is within the range of normal operations, and existing refineries appear to be able to meet the increased 2027 octane requirements with minor operational adjustments. No industry-wide capital intensive projects would be needed to meet the 2027 requirements.