INDONESIA FUEL ETHANOL COST-BENEFIT ANALYSIS STUDY

prepared for:

U.S. GRAINS
COUNCIL

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John Mayes
Samuel Davis
Michael Leger, P.E.

Turner, Mason & Company
energy consulting & advisory

P.O. Box 130808

Dallas, TX 75313
214-754-0898
www.turnermason.com

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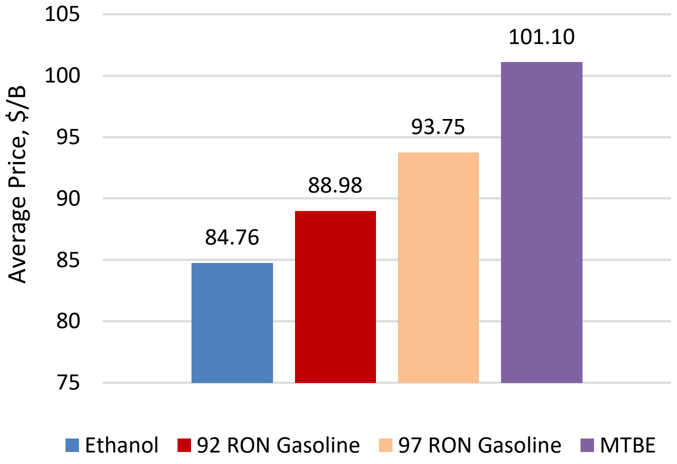
I. EXECUTIVE SUMMARY

The role of oxygenates and biofuels in the global transportation fuel mix is steadily growing. While there are a number of fuels in these two categories, ethanol is the only fuel which is in both. As such, ethanol not only assists in the combustion process and reduces carbon monoxide emissions but is also a renewable biofuel which reduces the production of greenhouse gases. In addition to these benefits, the blending of ethanol in most years will reduce the cost of gasoline while the blending of other oxygenates, such as MTBE, will increase the cost. Figure I-1 is a comparison of the costs of ethanol delivered to Indonesia from the U.S. with spot Singapore prices for 92 and 97 RON gasoline and spot MTBE prices, also from Singapore[1]. These values are the average of prices from January 2012 through the first half of 2022, excluding 2020 and 2021. The years of 2020 and 2021 are excluded due to the extreme market pressures which resulted from the COVID-19 pandemic. As can be seen from Figure I-1, delivered ethanol prices were lower than 92 RON gasoline by $4.22 per barrel and less than MTBE by $16.34 per barrel.

FIGURE I-1
Adjusted Singapore Gasoline Prices, 2012-2022 (Excl. 2020-2021)



In addition to the significant economic benefits, the use of ethanol also creates other operational and strategic gains. Ethanol is generally added to gasoline with a computerized in-line blending system which can reduce octane give-away and ensure proper octane requirements are met. The use of ethanol also reduces the concentration of contaminants, like sulfur, and undesired compounds, such as benzene and other aromatics. There are also strategic advantages with ethanol in the form of a diversification of the transportation fuel supply. This is accomplished by moving away from petroleum and increasing the geographic sources of supply.

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[1] S&P Global Platts quotations, TM&C.

Economic Benefits

TABLE I-1

Cost Reductions from Adding Ethanol, $/B

	92 RON	97 RON
E5		
Pricing Benefits	0.21	0.45
Octane Benefits	1.81	1.57
Dilution Benefits	0.15	0.15
Total Reductions	**2.17**	**2.17**
E10		
Pricing Benefits	0.42	0.90
Octane Benefits	3.63	3.15
Dilution Benefits	0.30	0.30
Total Reductions	**4.35**	**4.35**
E15		
Pricing Benefits	0.63	1.35
Octane Benefits	5.44	4.72
Dilution Benefits	0.45	0.45
Total Reductions	**6.52**	**6.52**
E20		
Pricing Benefits	0.84	1.80
Octane Benefits	7.25	6.30
Dilution Benefits	0.60	0.60
Total Reductions	**8.70**	**8.70**

The direct economic benefits of ethanol come in three forms: 1) lower ethanol pricing which reduces the blended gasoline price, 2) higher ethanol octane which reduces the required subgrade octane, and 3) the use of ethanol creates dilution benefits. As seen in Figure I-1, ethanol is generally priced lower than regular gasoline with the result that the addition of ethanol will reduce the price of the blended fuel. The higher the concentration of ethanol, the greater the price reduction. The value of these pricing reductions is seen in Table I-1.

The octane benefit is the result of the 130 RON for ethanol[2]. This higher octane allows for a lower-octane subgrade to be blended with the ethanol, such that the blended fuel achieves its desired total RON requirement. The lower-octane subgrade is less expensive for a refinery to produce. Over the last ten years, octane in Singapore has been valued at $0.95 per RON. The octane benefits shown in Table I-1 are greater than the pricing benefits.

The third economic improvement is derived from the dilution benefits of ethanol. Indonesia's fuel specifications are generally less stringent than other G20 countries, but the nation is working toward tightening these requirements. This path is hampered, however, by slower than expected domestic refinery upgrades. Ethanol contains no benzene or aromatics and essentially no sulfur. While ethanol will not achieve the desired improvements by itself, it does represent a highly economic first step and could substantially reduce refinery investments to achieve the balance of the objectives. Turner, Mason & Company (TM&C) has estimated the financial impact of these dilution benefits at $0.30 to $0.60 per barrel.

In addition to the scenario of blending ethanol into clear gasoline (E0), TM&C also calculated the economic benefits of transitioning from a 10% MTBE blend to the various ethanol grades. These benefits are shown in Table I-2. The pricing improvements are greater in this case due to the

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[2] *Cleaner Fuels for Latin America with MTBE and ETBE Advanced Gasoline Components*, LyondellBasell.

TABLE I-2

Cost Reductions of Ethanol versus MTBE, $/B

	92 RON	97 RON
E5		
Pricing Benefits	1.42	1.18
Octane Benefits	-0.91	-0.64
Dilution Benefits	-0.15	-0.15
Total Reductions	**0.37**	**0.39**
E10		
Pricing Benefits	1.63	1.63
Octane Benefits	1.05	1.05
Dilution Benefits	0.00	0.00
Total Reductions	**2.68**	**2.68**
E15		
Pricing Benefits	1.84	2.08
Octane Benefits	3.01	2.74
Dilution Benefits	0.15	0.15
Total Reductions	**5.00**	**4.97**
E20		
Pricing Benefits	2.06	2.53
Octane Benefits	4.96	4.43
Dilution Benefits	0.30	0.30
Total Reductions	**7.32**	**7.27**

higher MTBE prices, but the octane contributions are lower as MTBE has a higher RON than the gasoline grades but less than that of ethanol. In total, the MTBE to E5/E10/E15/E20 case produces lower economic benefits than the E0 to the E5/E10/E15/E20 cases. This indicates there is value in utilizing MTBE but even great economic gain in utilizing ethanol. These two cases are described in greater detail in Sections IV and V.

Strategic Benefits

Not all of the benefits of ethanol blending can be quantified, but are real, nonetheless. The first of these is the ability to diversify the transportation fuel sources. Crude oil, and as a result gasoline prices, tend to be highly volatile. This volatility is generally much greater than that of ethanol prices. Transitioning 10% or more of the gasoline sourcing to ethanol, will reduce the dependence on crude oil and its corresponding volatility. The second component of diversification is related to geography. Incremental global crude oil is often supplied by politically unstable countries: such as Iraq, Iran, and Venezuela. Sourcing transportation fuels from the U.S. or Brazil helps to insulate against unexpected political disruptions.

A second strategic benefit results from aligning with global trends. In the last ten years, Indonesia has increased its octane requirements by two RONs as it mostly replaced 88 RON gasoline with 90 RON gasoline. Most other countries are also increasing their octane requirements in line with the trend of producing higher Euro grade fuels (Table I-3). The higher Euro gasoline grades require higher RONs, and lower sulfur, benzene, and aromatic levels. Current Indonesian specifications are similar to Euro II gasoline.

TABLE I-3
Indonesia and Euro Gasoline Specifications

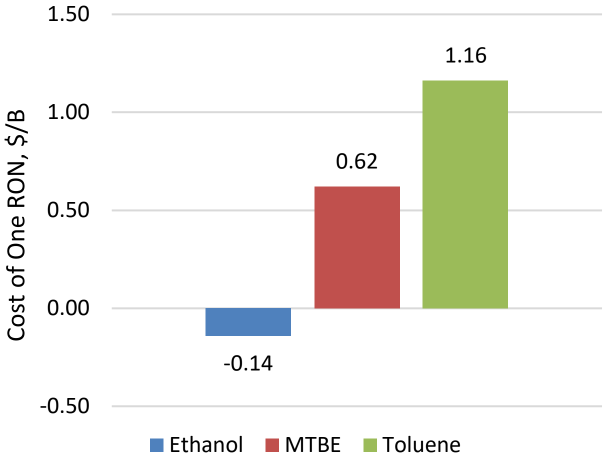
		Euro Grades				Current
Property	Units	Euro II	Euro III	Euro IV	Euro V	Indonesia
Implementation Year		1996	2000	2005	2009	
RON	Minimum	92	93	94	95	88+
Sulfur	Max. PPM	500	150	50	10	500
Benzene	Max. Vol. %	5	1	1	1	5
Aromatics	Max. Vol. %	---	42	35	35	50/40[3]

Other countries have also increased octane requirements in recent years and this trend is expected to continue into the near future. Ethanol, MTBE and toluene are currently being used to enhance gasoline octanes around the world. For the last ten years, ethanol has proven to be the least costly method to increase octane. Figure I-2 compares the cost to increase regular gasoline by one RON using each of the three compounds[4]. While ethanol would reduce the cost of regular gasoline by approximately $0.14 per barrel per RON, MTBE would increase the cost by $0.62 per barrel and toluene would raise the cost by $1.16 per barrel.

Conclusions

Because of the uncertainty of global politics and the volatility of oil prices, diversifying the transportation fuel sources would seem to be a rational decision. The validity of this approach is validated further by a decade of recent history which concludes that not only will the blending of ethanol increase the octane pool and improve the quality of the gasoline by reducing sulfur and benzene levels, but it can accomplish all of these objectives while reducing the cost of the gasoline at the same time. This is a feat no other additive can achieve.

FIGURE I-2
Relative Costs of Octane



While this report has quantified many of the benefits of blending ethanol, the basis of this analysis is best described as preliminary. Actual savings will be related to a series of variables related to the actual refining and blending capabilities of Indonesia as well as the strategic objectives of the country. As such, a second analysis of the full ethanol blending potential is recommended which is tailored to the capabilities and objectives of Indonesia and conducted with the government of Indonesia or Pertamina.

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[3] Domestic refineries may produce up to 50% aromatics until the end of 2024. All other gasoline must be below 40% aromatics.
[4] TM&C Octane Cost Analysis.

II. INTRODUCTION

There are several grades of gasoline sold in Indonesia. The dominant grades are 88 RON, 90 RON and 92 RON. These three grades comprise around 98% of gasoline sales[5]. The remaining volume is composed of premium grades which are up to 100 RON. While the variety of grades is not necessarily an issue, the gasoline qualities are. Gasoline sold in Indonesia generally has a sulfur specification of 500 ppm, which is substantively higher than other G20 nations. Also of concern is the high levels of benzene and other aromatic compounds. Overall, the quality of most Indonesian gasoline is equivalent to a Euro II grade, which was first introduced in Europe in 1996.

While Indonesia is attempting to improve the quality of its transportation fuels, the path has proven to be difficult; however, refining improvements are underway which will facilitate this process. Early progress in this direction has been made in the premium gasoline grades, but the requirements for the regular grades are still lagging. Table II-1 compares some of the fuel requirements. Sample retail data has been obtained by TM&C which indicates MTBE is widely used while none of the samples contained ethanol[6].

TABLE II-1

Indonesia Gasoline Grade Specifications

Property	88-92 RON	95+ RON
Sulfur (max. ppm)	500	50
Aromatics (max. vol. %)	50	40*
Benzene (max. vol. %)	5.0	5.0
Oxygen (max. wt. %)	2.7	2.7

* Gasoline produced by domestic refineries is permitted at 50% until the end of 2024.

Our analysis of the additional cost advantages for ethanol blends compared to clear gasoline or MTBE blended gasoline is based on the following assumptions.

- All appropriate Indonesian laws have been modified permitting the blending of either 5%, 10%, 15%, or 20% ethanol into the gasoline supply.
- All other current gasoline specifications for Indonesia remain in effect.
- Infrastructure required for ethanol transportation, storage, and blending are in place. This would include terminal and retail facilities. Vehicle compatibility with ethanol is also assumed.
- The pricing of gasoline and components was based on historical Singapore spot prices for 2012 through the first half of 2022 as reported by Platts.

For the task of assessing the cost savings of converting from MTBE blends to ethanol blends, we reviewed the historical pricing differences between MTBE and ethanol and evaluated the octane

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[5] *Handbook of Energy & Economic Statistics of Indonesia, 2021.*

[6] *SGS Worldwide Gasoline Survey Summer 2019*.

contribution each makes to gasoline blends. For purposes of this analysis, we used an MTBE RON of 119 and ethanol RON of 130.

III. BACKGROUND AND SCOPE

TM&C was retained by the U.S. Grains Council to assess the economics of blending E5, E10, E15, and E20 ethanol grades in Indonesia. TM&C also assessed the economics of blending E5, E10, E15, and E20 compared to an alternate case of blending 10% MTBE. The basis for these economics was the use of Singapore spot prices from S&P Global Platt's databases. TM&C evaluated a series of benefits of ethanol: including advantaged pricing, octane values, and the dilution effects on other gasoline specifications. The scope of work focused on the following:

1) The cost savings of producing an E5, E10, E15 and E20 versus no oxygenate blending;
2) The cost savings for producing an E5, E10, E15, and E20 compared to the use of MTBE;
3) The cost of producing octane in a global environment of increasing octane requirements; and
4) Gasoline Market Overview with a focus on supply, demand and imports.

To assess the cost of ethanol, this study utilizes Platts pricing data for U.S. Gulf Coast (USGC) quotations. These pricing assessments are predominantly utilized for domestic sales which are presumed to incorporate the value of a D6 RIN. When ethanol is exported, EPA regulations require the RIN which is attached to the ethanol to be retired. As such, no value of the RIN is received by either the buyer or the seller of the ethanol. Because of this, the Platts quotations for domestic sales of ethanol likely overstate the cost of ethanol when it is exported, resulting in the ethanol pricing benefits in this analysis being similarly understated.

IV. Benefits of E5/E10/E15/E20 Compared to E0

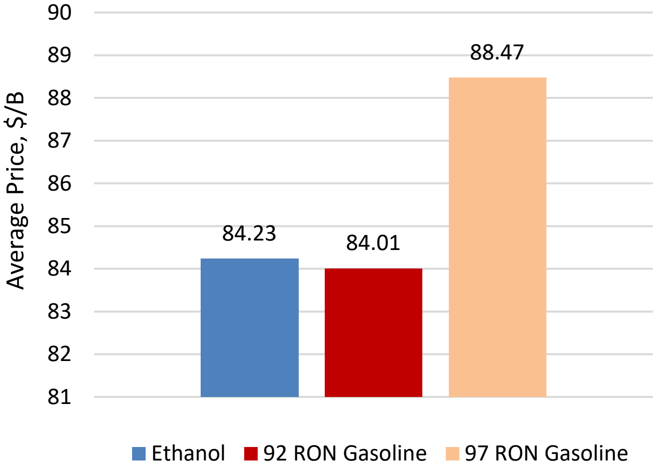
The assessment of production cost savings resulting from a transition from E0 to E5/E10/E15/E20 blends in Indonesia starts with the premise that the regulations have already been approved to blend ethanol and the benefits of various ethanol concentrations are being evaluated. Also, all of the infrastructure for the transportation, storage and blending of ethanol is assumed to be in place. As a result, the choice of the specific ethanol concentration would result in a seamless transition due to the computerized nature of the blending systems.

The advantages of ethanol blends over clear gasoline (E0) come in three distinct components. The first is that ethanol is generally priced lower than petroleum-based gasoline. Because of this, the cost of the blended fuel decreases as the ethanol concentration increases. The second advantage of ethanol blending is from an improvement in the octane of the fuel. Because of the higher ethanol octane, a lower octane of the petroleum gasoline subgrade is required to obtain the final desired octane of the blended mix. The third advantage is derived from the dilution effects of using greater concentrations of ethanol which contains no aromatic or benzene molecules and no sulfur.

Ethanol Pricing Effects

For the last decade, ethanol prices have been highly competitive with gasoline in most global markets. Since 2012, U.S. supplied ethanol has been priced slightly above the cost of 92 RON gasoline in Singapore[7] (Figure IV-1). The ethanol prices are based on USGC values with transportation expenses to Singapore (estimated at $3.41 per barrel). These historical costs may not provide an accurate assessment of future expenses, however. For most of the years during this period, the price of delivered ethanol was less than the price of 92 RON gasoline. Heavily impacting these historical values, however, were the COVID-19-driven years of 2020 and 2021. When these two years are excluded from the averages, ethanol

FIGURE IV-1
Historical Singapore Gasoline Prices, 2012-1H2022



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[7] S&P Global Platt's quotations.

prices were less than the 92 RON prices by $4.22 per barrel, instead of the $0.22 per barrel premium shown in Figure IV-1.

The adjusted historical prices (excluding 2020 and 2021) are shown in Figure IV-2. Because a 90 RON is currently the dominant gasoline grade in Indonesia, a computed value for this grade is shown based on the price spread of the 92 RON and 97 RON grades. In this comparison, delivered ethanol prices are lower than 90 RON gasoline by $2.31 per barrel and less than 97 RON by $8.99 per barrel. TM&C believes the values in Figure IV-2 are a more likely representation of the future than the values in Figure IV-1.

FIGURE IV-2
Adjusted Singapore Gasoline Prices, 2012-2022 (Excl. 2020-2021)

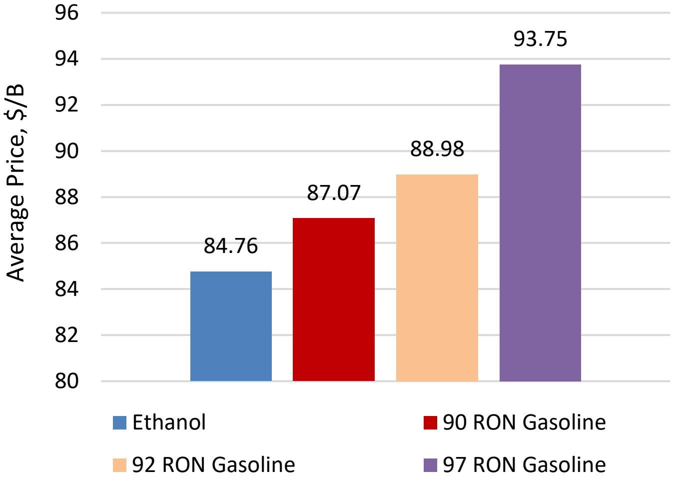


FIGURE IV-3
Historical Ethanol and 92 RON Gasoline Prices

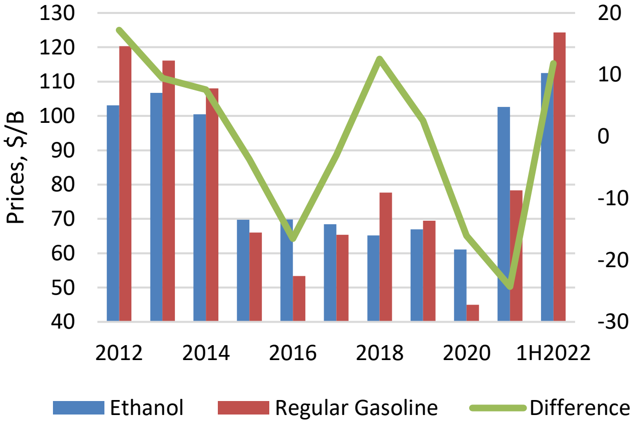


Figure IV-3 compares the yearly prices for delivered ethanol with 92 RON gasoline in Singapore (including 2020 and 2021). In six of the eleven time periods (including the first half of 2022), delivered ethanol prices were below 92 RON prices. As can be seen in Figure IV-3, gasoline prices collapsed in 2020 and 2021, and fell below ethanol values. Gasoline prices rebounded in the first half of 2022 and averaged nearly $12/barrel above ethanol prices. The ethanol/gasoline price also inverted in 2016 when gasoline prices were also low. The ethanol pricing discount loosely correlates to the absolute gasoline price.

Because the adjusted delivered ethanol prices are lower than the adjusted gasoline prices in Figure IV-2, blending ethanol into the gasoline pool will lower the combined fuel price. Table IV-1 details these cost reductions. Blending an E10 using 92 RON gasoline would have reduced the gasoline price by $0.42 per barrel while the price reduction

TABLE IV-1

Adjusted Pricing Benefits, $/B		
	92 RON	97 RON
E5	0.21	0.42
E10	0.42	0.90
E15	0.63	1.35
E20	0.84	1.80

for an E20 using 97 RON gasoline would have been $1.80 per barrel. The cost reductions increase as the ethanol concentration increases.

Octane Effects

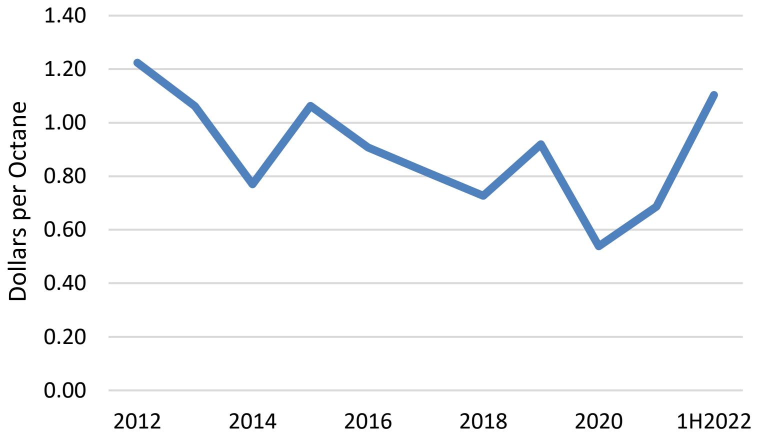
In addition to the pricing benefits, the blending of ethanol also provides substantial octane benefits. The financial impact of these octane increases can be much greater than the pricing benefits. Because ethanol has a high octane (130 RON), a higher ethanol concentration in the gasoline allows for a lower octane in the gasoline subgrade, which when combined, will produce the desired RON for the final regular gasoline blend. Table IV - 2 illustrates this point. When the ethanol concentration is at 10% (E10), the octane of the 92 RON subgrade can be 87.8 RON, such that the RON of the total mixture will be the desired 92.0. If the ethanol concentration is increased to 20% (E20), the octane of the subgrade need only be 82.5 RON to achieve an 92.0 RON for the total blend.

TABLE IV-2

Subgrade Octane Requirements, RON

	92 RON	97 RON
E5	90.0	95
E10	87.8	93.3
E15	85.3	91.2
E20	82.5	88.8

FIGURE IV-4
Singapore Octane Value



Decreasing the octane of the subgrade produces a financial benefit in that incremental octane has a defined cost. Using the Singapore pricing spread between 92 RON and 97 RON gasoline, the cost of one incremental RON can be computed. Figure IV-4 displays the yearly variations with this calculation which varies from $0.54 per octane to $1.22 per octane. The adjusted average of the last decade (excluding 2020 and 2021) was $0.95 per octane.

The combination of the octane savings in Table IV-2 with the historical cost of octane in Figure IV-4 will yield the total benefits of blending the various ethanol concentrations. These savings are seen in Table IV-3. The value of the octane benefits in Table IV-3 are significantly greater than the pricing benefits seen in Table IV-1.

TABLE IV-3

Adjusted Octane Benefits, $/B

	92 RON	97 RON
E5	1.81	1.57
E10	3.63	3.15
E15	5.44	4.72
E20	7.25	6.30

Dilution Effects

Because ethanol has no aromatic molecules (including benzene) and no or minimal sulfur, it is an excellent gasoline blendstock, particularly in regions where these contaminants are at high levels compared to their required specifications. The addition of ethanol would effectively reduce the levels of all of these contaminants while reducing the price of the fuel at the same time. While ethanol itself is devoid of sulfur, sulfur can be introduced by the addition of denaturants (generally gasoline) along with trace amounts from transportation, handling, and storage facilities. The U.S. EPA mandates using a nominal value of 5 ppm sulfur for Reformulated Gasoline reporting purposes when the sulfur content of the ethanol is not actually tested. This is the value which has been used for this study.

Europe has been on a multi-decade path to improve the fuel specifications of the gasoline consumed in the region (Table IV-4). The current specifications are for Euro V which was implemented in 2009 and requires a maximum sulfur level of 10 ppm and a benzene level of less than 1%. Most of the gasoline sold in Indonesia has a 500 ppm limit for sulfur and a cap of 5% for benzene. These current Indonesian requirements are equivalent to Euro II gasoline. The current objective of the Indonesian government is to achieve Euro IV specifications by 2025[8].

TABLE IV-4

Indonesia and Euro Gasoline Specifications

		Euro Grades				Current
Property	Units	Euro II	Euro III	Euro IV	Euro V	Indonesia
Implementation Year		1996	2000	2005	2009	
RON	Minimum	92	93	94	95	88+
Sulfur	Max. PPM	500	150	50	10	500
Benzene	Max. Vol. %	5	1	1	1	5
Aromatics	Max. Vol. %	---	42	35	35	50/40

Reducing the sulfur and benzene levels in Indonesian gasoline will require considerable effort and capital. The blending of ethanol will not achieve the Euro IV requirements by itself, but it could provide an easy and economic first step in this process. While the percent reduction in sulfur, aromatics, and benzene levels is dependent on the levels present in the gasoline subgrade, Table IV-5 details the linear reductions in a typical subgrade which is fully compliant with each of the specifications. For subgrades which are noncompliant, the ethanol blending benefits would be greater than those

TABLE IV-5

Dilution Effects for Ethanol Blending

	Typical	Blended Values			
Specification	E0	E5	E10	E15	E20
Sulfur	500 ppm	475	451	426	401
Aromatics	40 vol. %	38	36	34	32
Benzene	2.0 vol. %	1.9	1.8	1.7	1.6

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[8] *The Retail Fuels Market in Indonesia.* 2020 International Council on Clean Transportation. October 2020.

shown in Table IV-5. These reductions could become a critical component in the success of Indonesia's efforts to convert its gasoline specifications to a Euro 4 standard.

The total of the dilution effects is difficult to calculate and is highly country specific and refinery specific. TM&C estimates the total impact of the quality improvements related to ethanol dilution effects to be $0.15 per barrel for E5 and $0.60 per barrel for E20. These savings are achieved by reducing the environmental burdens on the domestic refineries which can improve the ability to produce higher Euro Grade gasolines.

Total Cost Reduction Benefits

TABLE IV-6

Cost Reductions from Adding Ethanol, $/B

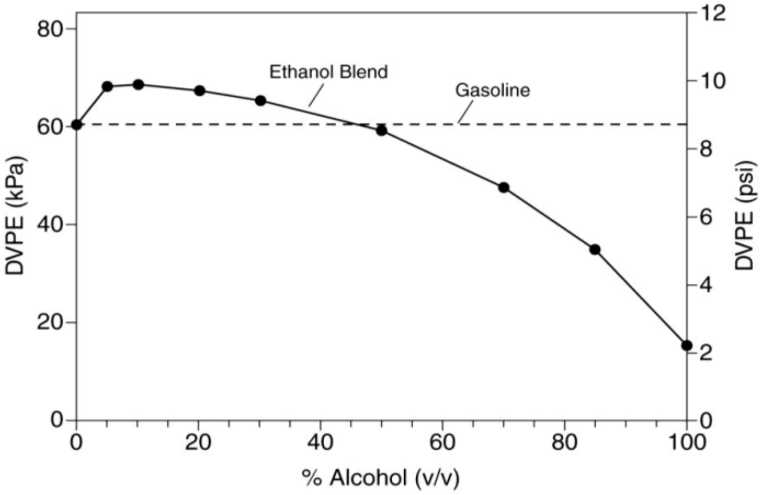
	92 RON	97 RON
E5		
Pricing Benefits	0.21	0.45
Octane Benefits	1.81	1.57
Dilution Benefits	0.15	0.15
Total Reductions	**2.17**	**2.17**
E10		
Pricing Benefits	0.42	0.90
Octane Benefits	3.63	3.15
Dilution Benefits	0.30	0.30
Total Reductions	**4.35**	**4.35**
E15		
Pricing Benefits	0.63	1.35
Octane Benefits	5.44	4.72
Dilution Benefits	0.45	0.45
Total Reductions	**6.52**	**6.52**
E20		
Pricing Benefits	0.84	1.80
Octane Benefits	7.25	6.30
Dilution Benefits	0.60	0.60
Total Reductions	**8.70**	**8.70**

The total cost reductions for transitioning from an E0 to the various ethanol blends are shown in Table IV-6. For an E10 92 RON, the total reduction in costs averaged approximately $4.35 per barrel for the last decade (excluding 2020 and 2021) while an E20 would have yielded a reduction in costs of approximately $8.70 per barrel. As can be seen in Table IV-6, the bulk of the savings is related to the octane benefits of blending ethanol.

The cost reductions for regular gasoline are equal to those for premium. The reason is that the octane values were calculated by comparing the spread in prices between 92 RON and 97 RON. As a result, when the 92/97 RON spread widened, the pricing impact increased but was offset by a reduction in the octane impact.

While the decade-long average of cost reductions was related to the ethanol concentration, there was considerable volatility in the yearly averages. For E10 regular, the yearly cost reductions were as low as $2.09 per barrel (excluding 2020 and 2021) but were as high as $6.67 per barrel. The E20 regular cost reductions were as high as $13.25 per barrel.

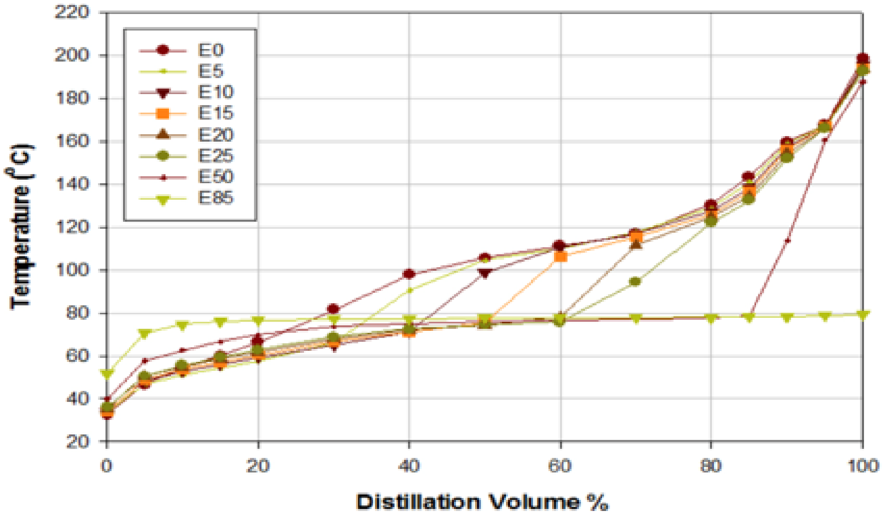
FIGURE IV–5
Effect of Ethanol Blending on Gasoline Vapor Pressure



Gasoline Volatility

Because of air quality issues, the vapor pressure of the gasoline is always of paramount importance. A reasonable concern which could arise in the conversion to various ethanol blends is the potential of a decrease in air quality due to an increase in the vapor pressure. While ethanol itself has a low RVP (around 2 psi), it is well established that ethanol/gasoline blends with low concentrations of ethanol (up to 10%) tend to increase the RVP of the blend. As the concentration of the ethanol increases above 10%, however, the vapor pressure of the blend decreases. This effect is shown in Figure IV-5 and was produced by the National Renewable Energy Laboratory[9] which validates that the vapor pressure of ethanol blends between 5% and 20% are essentially flat. As a result, while a 1 psi waiver would likely be necessary, no additional cost impacts relating to vapor pressure have been assumed for conversions to E5, E10, E15, or E20.

Figure IV-6
Ethanol Impacts on T50 Point



Another specification in which ethanol impacts gasoline volatility is the T50 point. This is the temperature at which 50% of the gasoline would be vaporized. Ethanol tends to lower the 50% point as illustrated in Figure IV-6[10] which depicts a typical E10 and E20 distillation curve compared to E0. This impact is relatively minor

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[9] "Discussion Document – Effect of Ethanol Blending on Gasoline RVP", letter to the Renewable Fuels Association, March 26, 2012, National Renewable Energy Laboratory.

[10] "Distillation Curves for Alcohol-Gasoline Blends", Energy Fuels. V F Anderson, J E Anderson, T J Wallington, and S A Mueller.

for E10 and would not be a concern for most gasolines which are not light, i.e., highly volatile. Light gasoline, with a low pre-existing T50 point, could yield a blended T50 below desired levels or specification limits and will need additional evaluation

V. BENEFITS OF ETHANOL BLENDS VERSUS MTBE

While MTBE can also be considered as an oxygenate for use in Indonesian gasoline, ethanol is more advantageous in every respect. Ethanol is less expensive than MTBE, it has a higher octane than MTBE, and it can be used in higher concentrations than MTBE, resulting in greater dilution benefits. These total benefits serve not only to lower transportation costs for Indonesian consumers but will also reduce the refining upgrades necessary to produce higher Euro grades of gasolines in the future.

The most obvious benefit of ethanol is its lower price. Since 2012, the price of ethanol delivered to Indonesia was nearly $11 per barrel less than the price of MTBE (using Singapore pricing)[11]. When the COVID-19 years of 2020 and 2021 are taken out of this comparison, the ethanol pricing advantage rises to $16.34 per barrel (Figure V-1). For over 10 years, ethanol has been priced below regular gasoline while MTBE has been priced substantively over premium gasoline.

FIGURE V-1
Adjusted Singapore Gasoline Prices, 2012-2022 (Excl. 2020-2021)

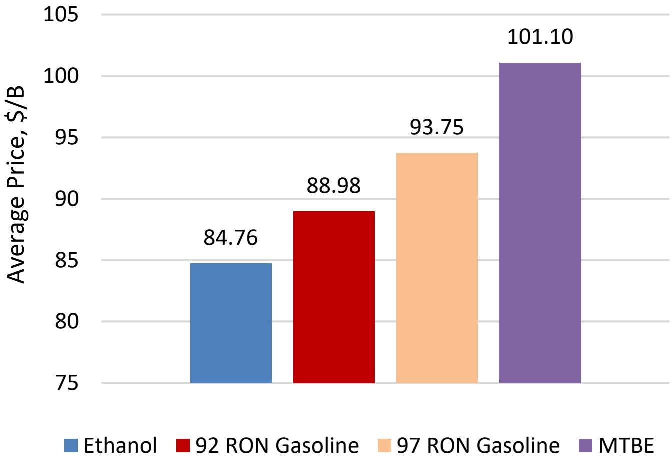
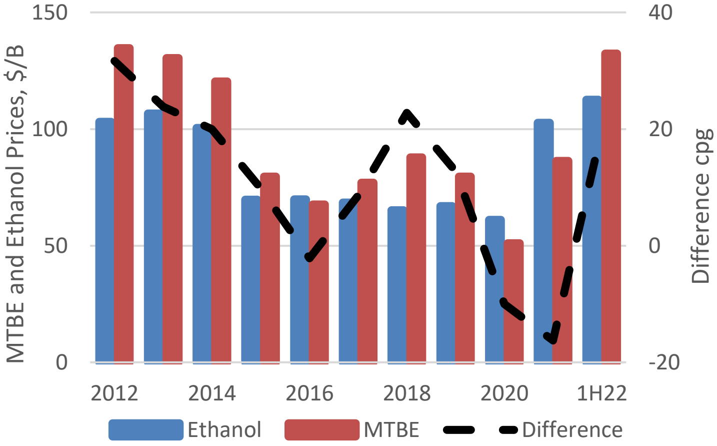


FIGURE V-2
MTBE/Ethanol Prices



In general, higher priced petroleum markets provide for greater discounts in ethanol pricing. Figure V-2 compares the yearly differences in ethanol and MTBE prices. In 2020, demand for MTBE plummeted, causing prices to fall below ethanol values. This condition carried into 2021. By 2021, however, global demand for MTBE recovered, pushing the 2022 price well above that of ethanol. MTBE prices were also below

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[11] S&P Global Platt's quotations.

ethanol in 2016, but only by $2.14 per barrel. The pricing inversion in 2016 was also related to weak petroleum prices.

The degree of savings generated by the blending of ethanol is related to the concentrations of the ethanol and MTBE. In countries where MTBE is utilized, concentrations are generally up to 10%. TM&C has compared the historical prices of blending 10% MTBE with ethanol grades of E5, E10, E15, and E20. Excluding the COVID-19 years of 2020 and 2021, the lower pricing of ethanol compared to MTBE would have reduced blended gasoline prices between $1.18 per barrel and $2.53 per barrel depending on the ethanol concentration and the grade of gasoline produced (Table V-1).

TABLE V-1

Reduction in Gasoline Prices
Ethanol vs 10% MTBE, $/B

Ethanol Grades	92 RON	97 RON
E5	1.42	1.18
E10	1.63	1.63
E15	1.84	2.08
E20	2.06	2.53

Because ethanol has a higher octane (130 RON) compared to MTBE (119 RON)[12], the gasoline subgrade which would be blended with each would have a lower required RON for ethanol than the subgrade for MTBE, except for E5. The value of the octane reduction can be measured by the difference in 92 RON and 97 RON Singapore prices. The average price difference for each year divided by the five octane difference would yield the historical value of one octane, as previously shown in Figure IV-4.

TABLE V-2

Reduction in Subgrade Octanes
Ethanol vs 10% MTBE, RON

Ethanol Grades	92 RON	97 RON
E5	-1.00	-0.71
E10	1.22	1.22
E15	3.71	3.38
E20	6.50	5.81

The octane reductions shown in Table V-2 multiplied by the cost of octane displayed in Figure IV-4 will calculate the value of the savings in usage of ethanol compared to a 10% MTBE blend. These values are shown in Table V-3 for the last 10.5 years (excluding 2020 and 2021). Depending on the ethanol concentration and the grade of gasoline, the value of the improved octane ranges between -$0.76 per barrel and $4.68 per barrel.

TABLE V-3

Historical Octane Benefit
Ethanol vs 10% MTBE, $/B

Ethanol Grades	92 RON	97 RON
E5	-0.76	-0.52
E10	1.05	1.05
E15	2.86	2.62
E20	4.68	4.20

As described in the previous section, Indonesia could derive substantial environmental benefits in blending ethanol. Ethanol blends would reduce sulfur, benzene, and aromatic levels while simultaneously reducing the cost of the gasoline. While ethanol blends would not reach Euro III gasoline qualities, they could provide a substantive step in that direction. By comparing these

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[12] *Cleaner Fuels for Latin America with MTBE and ETBE Advanced Gasoline Components*, LyondellBasell.

dilution benefits with that of 10% MTBE, TM&C assesses the financial savings at -$0.15 per barrel for E0, $0.00 per barrel for E10, $0.15 per barrel for E15 and $0.30 per barrel for E20. The E10 is assumed to have no improved dilution benefits as it is compared with a comparable 10% MTBE blend.

The total economic value of blending the various ethanol grades with 10% MTBE for the last 10.5 years (excluding 2020 and 2021) are shown in Table V-4. The level of benefits ranges from $0.37 per barrel to $7.32 per barrel.

TABLE V-4

Cost Reductions of Ethanol versus MTBE, $/B

	92 RON	97 RON
E5		
Pricing Benefits	1.42	1.18
Octane Benefits	-0.91	-0.64
Dilution Benefits	-0.15	-0.15
Total Reductions	**0.37**	**0.39**
E10		
Pricing Benefits	1.63	1.63
Octane Benefits	1.05	1.05
Dilution Benefits	0.00	0.00
Total Reductions	**2.68**	**2.68**
E15		
Pricing Benefits	1.84	2.08
Octane Benefits	3.01	2.74
Dilution Benefits	0.15	0.15
Total Reductions	**5.00**	**4.97**
E20		
Pricing Benefits	2.06	2.53
Octane Benefits	4.96	4.43
Dilution Benefits	0.30	0.30
Total Reductions	**7.32**	**7.27**

VI. GLOBAL OCTANE REQUIREMENTS

As global efforts to reduce the production of greenhouse gases increase, one of the dominant pathways has been the improvement of fuel economies in the transportation fleet. If automobiles can travel farther on a gallon of fuel, then they will emit less greenhouse gases per mile traveled. As a result, government actions around the world have stimulated increased mileage requirements in new vehicle sales.

Auto manufacturers have adopted numerous methods to improve vehicle fuel efficiencies: such as lighter and more streamlined designs, more gear ratios, and engines which cut off when idling. One of the more significant methods of improving fuel mileage is the use of turbochargers. Automobile turbochargers have been around for decades but have only recently become mainstream. It represents one of the only methods to increase vehicle fuel economy and driving performance simultaneously, but at a higher vehicle cost.

When gasoline is combusted inside the engine cylinders, two actions occur. First, the hydrocarbon molecules are converted primarily to carbon dioxide and water vapor. Secondly, heat is generated by the combustion process. Much of this heat is transferred to the gases inside the cylinder which causes the gases to expand. The expansion of the gases causes the piston to move inside the cylinder which provides motion for the vehicle. One of the shortcomings of this process, however, is that only about half of the heat generated by combustion is absorbed by the gases and used to propel the vehicle. The remaining heat radiates out of the engine and is lost. The turbocharger is designed to capture part of this waste heat and improve the vehicle efficiency.

A turbocharger is simply a fan which routes a portion of the already combusted gases which otherwise would exit the vehicle through the tail pipe back into the engine. These exhaust gases enter the cylinders along with fresh air but are forced in at a higher pressure by the fan. The result is that there are more molecules of gases in the cylinder immediately before the spark plug fires than otherwise would be without the turbocharger. The greater number of gas molecules mean more heat will be absorbed during combustion and less heat will radiate out from the engine.

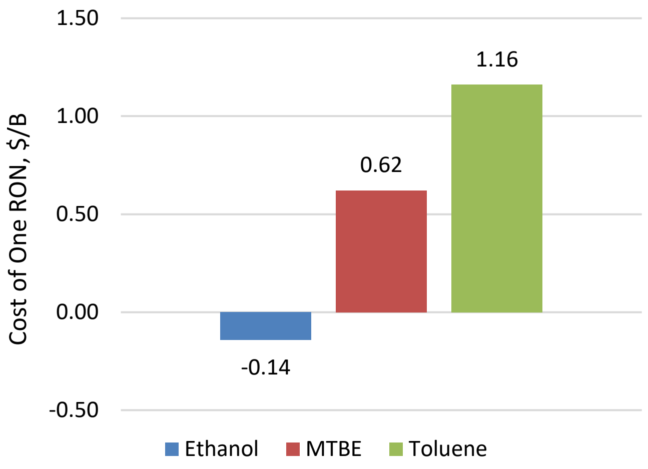
Because the engine operates at a slightly higher pressure due to the turbocharger, the engine will tend to knock easier. The solution to this issue is to provide a higher octane fuel which will resist the premature ignition. As turbocharged engines become more widespread around the world, global octane requirements are likely to increase. Most countries are already seeing this process occur.

Superchargers are the next step in the process and produce even greater efficiency gains. Instead of a fan, a supercharger utilizes a compressor to force more exhaust gases into the cylinder, causing the engine to operate at a higher pressure than a turbocharged engine. As a result, supercharged vehicles require even higher octane fuels.

In the last ten years, octane requirements in Indonesia have increased by about 2.0 octane primarily as a result of the 90 RON regular largely replacing the 88 RON regular. This trend is not unique to Indonesia, however. Mexico has seen a gasoline shift increase by 0.5 octane in the last decade while the U.S. has registered a meager increase of 0.12 octane. While many factors are contributing to this process, it is clear that fuel efficiency gains are impacting global octane requirements.

One of the benefits of ethanol is that it represents the least expensive path to increase gasoline octane. In fact, during most years of the last decade, the addition of ethanol would have decreased gasoline production costs. Figure VI-1 is a comparison of the cost to increase a regular gasoline (90 RON) by one octane using ethanol, MTBE, and toluene based on average prices for the last 10.5 years[13]. The use of ethanol would have reduced the cost of the gasoline by $0.14 per barrel while MTBE would have increased the cost by $0.62 per barrel and toluene by $1.16 per barrel.

FIGURE VI-1
Relative Costs of Octane



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[13] TM&C Octane Cost Analysis.

VII. GASOLINE MARKET OVERVIEW

Gasoline Market

The current refining system in Indonesia comprises eight facilities which have a total capacity of slightly over 1.1 million BPD. The refineries have a moderate degree of complexity with most possessing cracking or hydrocracking capabilities but only one with coking capacity[14]. The average size of the Indonesian facilities is 139 MBPD, which is slightly smaller than the U.S. average of 145 MBPD. The refineries process most of the indigenous crude production of Indonesia which has recently ranged between 600 MBPD and 700 MBPD.

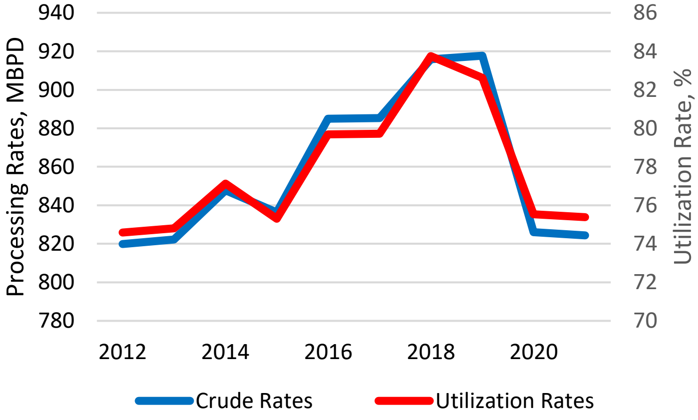
Until 2020, the Indonesian refining sector had been steadily improving crude processing and utilization rates (Figure VII-1). From 2012 through 2019 crude rates rose from 820 MBPD to 918 MBPD, causing utilization rates to increase from less than 75% of capacity to nearly 83% of capacity[15]. In 2020, however, crude rates plummeted to 826 MBPD as a result of the COVID-19 pandemic. Operating rates remained flat in 2021.

TABLE VII-1
Capacities of Indonesian Refineries

	MBPD
Balikpapan	247
Balongan	125
Cepu	3
Cilacap	348
Dumai	120
Musi	118
Sungai	50
Tuban	100
Total	**1,112**

Historically, Indonesian refineries have supplied less than half of the country's gasoline demand requirements. In the last decade, the percent of gasoline produced by the refineries ranged from a low in 2013 of 38% of Indonesia's requirements to a high of 47% in 2020. The average of the last ten years has been a production rate of 43%. The balance of the consumption requirements has been supplied by imports.

FIGURE VII-1
Indonesian Refinery Operating Rates



Indonesia experienced steady gasoline demand growth from 2012 through 2019 (Figure VII-2). Over this

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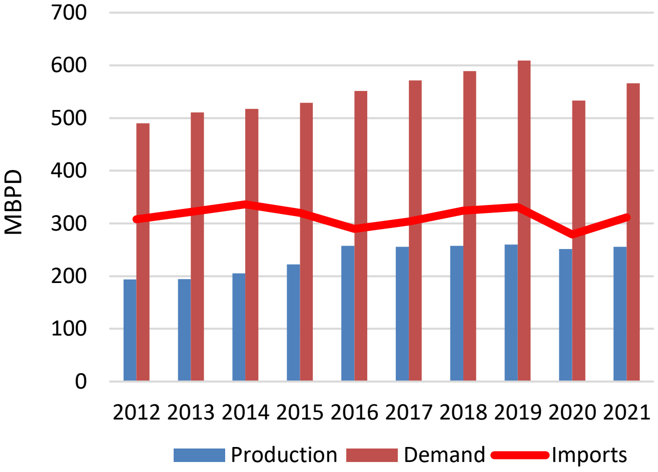
[14] Oil & Gas Journal, *Worldwide Total Refining Survey*

[15] *BP Statistical Review of World Energy.* June 2022.

period, demand rose from 490 MBPD to 609 MBPD, an annual increase of 3.2%[16]. The COVID-19 pandemic in 2020 caused demand to fall to 533 MBPD in 2020, approximately equal to what it was in 2015. About 85% of the 2020 demand decline was offset by a reduction in gasoline imports while refining production was only slightly lower. A robust rebound occurred in 2021, with demand rising to 566 MBPD, an increase of 6.2%.

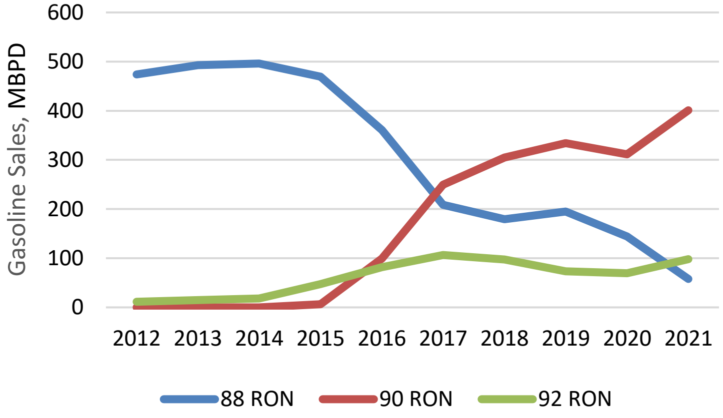
FIGURE VII-2
Indonesia Gasoline Supply and Demand Balance



Gasoline Grades

There has been a significant shift in the consumption of gasoline grades in Indonesia in recent years. Figure VII-3 displays the yearly sales of the three dominant grades: 88 RON, 90 RON and 92 RON[17]. Through 2014, the largest selling grade by far was the 88 RON, accounting for 96% of total gasoline sales. In 2015, however, the government ended subsidies on the grade and restricted sales in Java, Madura and Bali (the country's most populated regions). This caused sales to plummet as the government introduced 90 RON gasoline. In 2021, 90 RON gasoline comprised 71% of Indonesian gasoline sales while 88 RON sales fell to 10% of the total. Over the same period, 92 RON sales have grown robustly and now comprises the country's second highest sales at 17% of the total. Not shown in Figure VII-3 are the premium gasoline sales of 95 RON, 98 RON, and 100 RON. Together, these sales only account for 1.5% of the Indonesian gasoline market.

FIGURE VII-3
Indonesian Gasoline Sales by Grade



Gasoline Specifications

As discussed in Section IV, gasoline specifications in Indonesia lag most G20 countries. With the exception of the 95+ RON premium grades, the maximum sulfur limit is 500 ppm, a level

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[16] *Handbook of Energy & Economic Statistics of Indonesia, 2021.*
[17] *Handbook of Energy & Economic Statistics of Indonesia, 2021.*

introduced in Europe in 1996 (Table IV-4). The premium grades currently have a sulfur limit of 50 ppm which is equivalent to a Euro IV grade. Under the current timeline, all Indonesian sulfur limits will not decrease to 50 ppm until 2025. Previous sulfur reduction targets have not always been met as the public has been reluctant to shift to higher octane grades. This is largely tied to the reality that over 80% of the vehicles in Indonesia are motorcycles.

To ensure there are sufficient higher-octane gasolines in the future, Pertamina has embarked on two aggressive programs to upgrade domestic refinering capacity from its current level of 1.1 million BPD to 2.0 million BPD by 2025. The Refinery Development Master Plan (RDMP) is to upgrade five existing refineries while the Grass Root Refinery (GRR) project is to add another new 300 MBPD refinery in Tuban. Success of these programs will depend on how well they are executed. If these upgrades are not completed, additional fuel improvements to Euro III or higher will likely be linked to increased gasoline imports.

The importance of improving the gasoline fuel quality in Indonesia is widely accepted. Not only are sulfur emissions a dominant topic but also efforts to reduce benzene and aromatic levels. Benzene is a known carcinogen and high aromatic levels have been linked to higher carbon monoxide and particulate emissions. A 2015 study indicated pollution from tailpipe emissions in Indonesia was linked to 7,000 premature deaths with a cost of $4 billion[18]. While ethanol by itself will not achieve Indonesia's path to cleaner fuels, it can represent a significant step in that direction.

The current gasoline specifications for each grade are shown in Table VII-2.

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[18] Susan Anenberg, Josh Miller, Daven Henze, and Ray Minjares, *A Global Snapshot of the Air Pollution-Related Health Impacts of Transportation Sector Emissions in 2010 and 2015, (ICCT; Washington D.C., 2019)*

TABLE VII-2

Indonesia Gasoline Specifications

Grade	RON 95	RON 91	RON 90	RON 88	RON 98
Effective Date	Mar, 2006	Mar, 2006	Nov, 2017	Nov, 2017	Jun, 2018
RON, min	95.0	91.0	90.0	88.0	98.0
Sulfur, ppm, max	500	500	500	500	50
Lead, g/l, max	0.013	0.013			
Lead, g/l			Not permitted	Not permitted	Not permitted
Manganese, g/l, max			0.001	0.001	
Manganese, g/l	Not detectable				Not detectable
Benzene, vol%, max	5.0	5.0			5.0
Aromatics, vol%, max	40.0	50.0			40.0 (2)
Olefins, vol%	(3)	(3)	Report	Report	(3)
RVP @ 37.8°C (100°F), kPa, min	45	45	45	45	45
RVP @ 37.8°C (100°F), kPa, max	60	60	69	69	69
Density @ 15°C (60°F), kg/m3, max	770	770	770	770	770
Density @ 15°C (60°F), kg/m3, min	715	715	715	715	715
T10, °C, max	70	70	74	74	70
T50, °C, min	77	77	77	75	75
T50, °C, max	110	110	125	125	125
T90, °C, max	180	180	180	180	180
T90, °C, min	130	130			130
FBP, °C, max	205	215	215	215	215
Residue, vol%, max	2.0	2.0	2.0	2.0	2.0
Oxygen, wt%, max	2.7 (4)	2.7 (4)	2.7 (4)	2.7 (4)	2.7 (4)
Methanol, vol%	Not permitted	Not permitted		Not permitted	Not permitted
Ethanol, vol%, max	10 (4)	10 (4)			
Iron, g/l, max			0.001	0.001	
Iron, g/l	Not detectable				Not detectable
Silicon, ppm	Not detectable				Not detectable
Phosphorus, g/l	Not detectable				Not detectable
Oxidation stability, minutes, min	480 (3)	480 (3)	360	360	480
Sediment, wt%	(7)	(7)	(7)	(7)	(7)
Gum (solvent washed), mg/100ml, max	5	5	5	5	5
Gum (solvent unwashed), mg/100ml, max	70	70	70	70	70
Copper corrosion, 3hr @ 50°C, merit (class)	1	1			1
Copper corrosion, 3hr @ 50°C, max			1	1b	
Doctor test	Negative	Negative			
Sulfur, mercaptan, wt%, max	0.0020	0.002	0.002	0.002	0.002
Color	Yellow	Blue	Green	Yellow	Red
Odor					
Appearance	Clear and bright	Clear and bright	Clear and bright	Clear and bright	Clear and bright
Dye content, g/100 l, max	0.13	0.13			
Use of additives	(8)	(8)	(8)		(8)

(1) Trace amounts from crude petroleum, intentional addition is not allowed

(2) Gasoline produced by domestic refineries is permitted to contain up to 50 vol% aromatics until the end of 2024.

(3) If the olefins content is above 20 vol%, the minimum oxidation stability (induction period) shall be 1,000 minutes.

(4) When oxygenate is used, this ether is preferred. Bioethanol content refers to the Minister of Energy and Mineral Resources Regulation No. 12 of 2015 concerning the Third Amendment to the Minister of Energy and Mineral Resources Regulation No. 32 of 2008 concerning Provision, Utilization and Administration of Biofuel as Other Fuels. Higher carbon alcohol (C> 2) is limited to a maximum of 0.1% volume. The use of methanol is not permitted.
(5) pH 7-9
(6) Reference in-house methods with detection limit = 1 mg/kg
(7) 1 mg/l max
(8) Deliberate addition of metallic and deposit-forming additives is prohibited. Additive must be compatible with vehicle engines.

VIII. GLOSSARY OF TERMS

AKI	Anti-Knock Index. The measure of a fuel's ability to resist premature ignition. The average of the fuel's Motor Octane Number (MON) and its Research Octane Number (RON).
Aromatic	Hydrocarbon molecule in a ring formation and a specified hydrogen to carbon ratio.
Barrel	42 U.S. gallons. Approxately 159 liters.
BPD	Barrels per day.
CBOB	Conventional gasoline before the addition of an oxygenate.
Cpg	U.S. Cents per gallon.
E0	Gasoline without ethanol.
E5	Gasoline which contains 5% ethanol.
E10	Gasoline which contains 10% ethanol.
E15	Gasoline which contains 15% ethanol.
E20	Gasoline which contains 20% ethanol.
Gallon	Approximately 3.79 liters.
G20	19 large, industrialized nations along with the European Union.
GRR	Grass Root Refinery
MBPD	Thousand barrels per day.
MON	Motor Octane Number. The gasoline octane when the engine is at a full throttle or high speed.
MTBE	Methyl tertiary-butyl ether. A common gasoline oxygenate.
Olefin	Hydrocarbon molecule in a chain formations deficient in hydrogen.
RBOB	Reformulated gasoline before the addition of an oxygenate.
RDMP	Refinery Development Master Plan
RON	Research Octane Number. The gasoline octane when the engine is at a low speed.
RVP	Reid Vapor Pressure. A measurement of the volatility of gasoline.
TM&C	Turner, Mason & Company.
USGC	U.S. Gulf Coast.

IX. TM&C QUALIFICATIONS

Founded in 1971, TM&C provides technical, commercial, and strategic consulting services to worldwide clients in the crude oil, midstream, refining, refined products, and biofuels industries. For nearly 50 years, we have undertaken various single and multi-client consulting engagements along with research products covering crude oil, feedstocks, refining, and refined products outlooks. Our core competencies include individual refinery, company and refining industry studies, technical and commercial support in mergers and acquisitions, transaction due diligence, economic, feasibility and market analyses, expert witness as well as attestations and fuels regulatory support.

TM&C has had an active involvement in fuels studies in the U.S. and international markets for almost five decades. Such studies have included engagements with industry associations, governmental agencies and with individual companies and multi-client subscribers. The following is a summary of relevant past studies and engagements.

Representative Past Study Team Fuels Engagements

Mexico Fuel Ethanol Cost-Benefit Analysis Study
U.S. Grains Council, May 2020

Mexico Downstream Refining, Midstream, and Retail Offering
Multi-Client Study, October 2019

Energy Reform under AMLO
Mexico Energy Intelligence, June 2018

Outlook for Gasoline Pricing in Mexico
Industry Forum Presentation, April 2017

Mexico Export Market Opportunities for US Gulf Coast Refiners
Multi-Client Study, October 2016

Reformulated Gasoline Survey Association, 2000-Present
TM&C provides QA/QC Oversight to the National Program at Retail Stations & Labs

95 RON Gasoline Study
American Fuel & Petrochemical Manufacturers, 2016-Present

Independent Engineer Reviews of International Biofuels Facilities – Ongoing since 2010
Provide IE Reviews of Facilities for Registration with US EPA

Gasoline Octane Screening Study
American Fuel & Petrochemical Manufacturers, February 2014

Impact of the Energy Reform on Mexico's Refining Industry
Presented at Oil & Gas conference, May 2014

Economic and Supply Impacts of a Reduced Cap on Gasoline Sulfur Content
American Petroleum Institute, February 2013

Potential Tier III Gasoline/Lower Aromatics and Increased Octane – An Analysis of Economic and Supply Implications
American Petroleum Institute, 2011/ 2012

Ultra-Low Sulfur Diesel Planning Study/Survey
Multi-Client Study in conjunction with Colonial Pipeline, 2004/2005

Costs/Impacts of Distributing Potential Ultra Low Sulfur Diesel
American Petroleum Institute, February 2000

Initial Ballpark Assessment: CARB 3 RFG Potential Regulations and MTBE Ban
Western States Petroleum Association, November 1999

Costs of Potential Ban of MTBE in Gasoline
Lyondell Chemical Company, April 1999
Presented to EPA Blue Ribbon Panel on MTBE

Saudi Aramco, Two Major Studies, 1990s
Optimization of Fuels Distribution in The Kingdom

Review and Critique of the Economics Portion of "Health and Environmental Assessment of MTBE" University of California at Davis – November 1998
Oxygenated Fuels Association, December 1998

Reformulated Gasoline Study
New York State Energy Research and Development Authority, October 1994

U.S. Petroleum Refining: Meeting Requirements for Cleaner Fuels and Refineries
National Petroleum Council, August 1993
Modeling performed by TM&C

Alternate Gasoline Formulation Costs: Results of U.S. Refining Study
Economics Committee of the Auto/Oil Air Quality Improvement Research Program, April 1992

Cost Impacts of Potential CARB Phase 2 Gasoline Regulations
Western States Petroleum Association, November 1991

Reformulated Gasoline: The Impacts on Related Industries
Multi-Client Study, August 1991

Future Reformulated Gasolines, WSPA/CARB/GM, RVP/Drivability Index Emissions Testing Program
Western States Petroleum Association, August 1991
Developed the gasoline blends used in the test
U.S. Gasoline Outlook 1989-1994: Changing Demands, Values and Regulations
Demands, Modeling and Values – TM&C
Multi-Client Study, 1989

API Screening Study of Reformulated Gasoline
American Petroleum Institute, December 1989

U.S. Gasoline RVP Reduction Capabilities and Costs
American Petroleum Institute, November 1987

U.S. Gasoline Production Capabilities and costs
Multi-Client Study, November 1986

U.S. Petroleum Refining Capabilities
National Petroleum Council, October 1986
Modeling performed by TM&C