SGS

INSPIRE

LATIN AMERICA
ETHANOL BLENDING IN GASOLINE

September 2021

Current status: September 2021

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EXECUTIVE SUMMARY

SGS INSPIRE has carried out this report for the U.S. Grains Council to provide an understanding on how ethanol blending with gasoline can impact fuel quality and influence the progress towards achieving goals associated with gasoline emissions in the Latin American region. The report comprises a regulatory review of legislative and standards requirements for fuel quality, a summary of the laboratory tests performed on gasoline-ethanol blends from selected Latin American countries and information on optimal characteristics of blendstocks for gasoline to blended with ethanol. Below is a summary of the key takeaways from the study divided by sections.

1. Section 1 Country profiles: regulations, gasoline and blendstocks

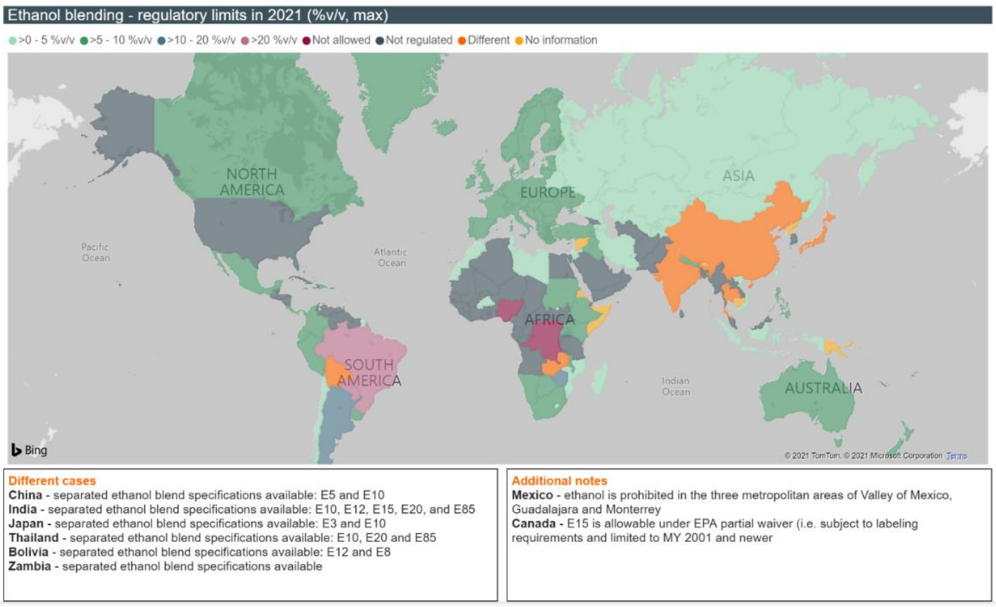
   In most Latin American countries, the refining industry is unable to meet domestic gasoline demand, hence imports are required. United States (U.S.) is the major importer in the region, particularly in Central America, with the exception of Nicaragua where the refining industry is relatively well developed and moreover, imports to this country are mainly originating in Ecuador.

   In countries with an existing refining industry, refineries have different unit configurations and capacities, physical locations, and are under different economic drivers. This is why they produce different gasoline byproducts or finished gasolines. Gasoline suppliers usually run one to six grades simultaneously and the quality of each batch of the gasoline's blendstock differs, depending on what blendstocks (compliant with specifications) are the cheapest at the time of production.

   In Latin America, the two blendstocks used the most are catalytic gasoline and reformate. Argentina, Chile, Colombia, and Mexico produce also other blending components because they have more complex refineries.

   Ethanol is added to gasoline blendstocks in many parts of the world for various reasons, as shown in Figure 1. Several Latin American countries have well-established domestic ethanol industries, however imports of U.S. ethanol to the region are growing, which is visible particularly in Peru, Mexico, Jamaica, and Colombia.

Figure 1: Ethanol in conventional gasoline allowed, 2021



Source: SGS INSPIRE, 2021

When comparing national gasoline specifications with actual gasoline quality in the region, a high compliance can be observed, except for the content of ethanol and octane in several samples.

2. Section 2: Gasoline component optimizations for ethanol blending

   Information from national sources and Penn Energy research provided data about the gasoline blendstocks produced domestically in the region. The optimized blending components mix for countries with simple refineries is composed mainly of reformate, catalytic gasoline and isomerate. In the case of countries with more complex refineries (Argentina, Chile, Colombia, and Mexico) or high import volumes, the blending components mix is composed of reformate, catalytic gasoline, isomerate, isobutane and alkylate, in different proportions.

   Most Latin American refineries have simple configurations and they produce simple by-products because of their inability to produce high octane and low sulfur fuels without having a high content of aromatics. Importing countries purchase what is available on the market.

   Using a Excel-based (Solver) blend optimization modelling tool, it is shown that the addition of ethanol into gasoline could reduce the need for use of complex and expensive gasoline blending components such as alkylate or isopentane to improve gasoline quality, because ethanol increases octane and decreases hydrocarbons and sulfur content of the blend. Increasing the share of ethanol in gasoline would help governments accelerate their plans to improve fuel quality. This is particularly the case of Bolivia, Ecuador, or Colombia.

   Many countries could increase their ethanol share by reducing the share of catalytic gasoline, which is however a very extended refinery by-product in the region, like Argentina or Colombia. Some countries, mainly in the Caribbean or the Northern part of South America, must add more complex and expensive blendstocks to meet Euro 6 enabling fuel quality specifications.

3. Section 3: Analysis of the potential impact of ethanol blending on emissions

   Using the International Vehicle Emissions (IVE) model, SGS INSPIRE has analyzed the potential impact of ethanol blending in gasoline at different levels (10%, 15%, 20%, 25% and 30%) on non-regulated emissions' parameters: carbon monoxide (CO), volatile organic compounds (VOC), evaporative volatile organic compounds (VOC evap), nitrogen oxides (NO_X), sulfur oxides (SO_X), ammonia (NH_3), lead, butadiene, acetaldehydes, formaldehydes, benzene, carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), particulate matter with diameters less than 10 micrometers (PM10) and particulate matter with diameters less than 2.5 micrometers (PM2.5).

   SGS INSPIRE collected information about vehicle fleets per type of vehicle and fuel in each country from international and national sources, in addition to information about average age of the vehicle fleet, average distance drove by type of vehicle per country, geographical and weather conditions (altitude, humidity, temperature) per country.

   In most of the analyzed gasoline-ethanol blends, emissions of CO, VOC, NO_X, SO_X, NH_3, butadiene, formaldehydes, benzene, CO_2, N_2O, PM2.5 and PM10 decrease with the addition of ethanol. Butadiene emissions do not decrease for some countries, like Bolivia or Chile, but they are still very low compared to other countries. Acetaldehydes emissions increase only after E20, i.e. when 20% v/v ethanol is added to gasoline. With 30% v/v ethanol blended into gasoline, acetaldehydes emissions increase 10% from the baseline or E0 (0% v/v ethanol added). This increase is significantly lower compared to the 62% decrease in benzene emissions observed from E30 to E0 in all countries. According to the U.S. Environmental Protection Agency (EPA), acetaldehydes have low acute toxicity from inhalation and moderate acute toxicity from oral or dermal exposure.

   The highest emissions of all are from CO_2. Emissions of N_2O do not decrease significantly. CO emissions differ in the region. They are high in the countries with old vehicle fleets that do not implement strict vehicle emissions standards. In Ecuador, benzene emissions are the only ones different between the two octane grades studied.

Comparison of emissions from different gasoline grades by octane shows that some countries use the same blendstock for oxygenate blending (BOB) and experience the same emissions, like Chile, Colombia or Dominican Republic; other countries use very similar BOB, like Costa Rica, and other countries use different BOB, which is the case of Argentina. In Argentina, emissions of VOC evap, lead, benzene, CO_2, N_2O, CH_4, PM2.5, PM10 are the same for the two grades (grade 2 with 150 mg/kg sulfur and grade 3 with 10 mg/kg sulfur), while emissions of CO, VOC, NO_X, SO_X, NH_3, butadiene, acetaldehydes and formaldehydes decrease when octane increases.

4. Section 4: Case studies of potential impact of ethanol on regulated parameters: Chile, Dominican Republic, Guatemala, and Peru

SGS collected samples of finished gasoline in fuel stations of Chile, Dominican Republic, Guatemala, and Peru. The samples were transported to the laboratory of SGS in Speyer, Germany, and there they were splashed blended with ethanol meeting EU standard EN 15376 in increasing volumes (10%, 15%, 20%, 25% and 30%).

These countries were selected for their representativeness for the different Latin American subregions and for their potential ethanol consumption.

According to the analysis performed, sulfur and hydrocarbons (naphthenes, aromatics, olefins, paraffins and benzene) decrease with the addition of ethanol, reducing tailpipe emissions at the same time.

RVP increases up to E10-E15, depending on the country. After reaching 15% v/v, RVP starts decreasing; this decline is more pronounced as more ethanol is added.

Distillation values do not change significantly except for the reduction of T50 from E0 to E15; however, it can be concluded that the addition of ethanol does not affect distillation.

Oxygen content for E10 in Chile is higher than what is allowed in the "Euro" standards (3.7% wt.). In Peru and Dominican Republic, the oxygen content is below the 3.7% wt. included in the "Euro" standards.

The addition of ethanol to gasoline, even though ethanol is hygroscopic, does not significantly affect the water content in the final blend. Hydrocarbon-alcohol blends can dissolve more water than exists at the time of blending and will provide protection against phase separation should small amounts of additional water contaminate the blended fuel as long as the blend's temperature does not decrease. The level of improvement in water tolerance (the amount of water that can be dissolved before phase separation occurs) will increase with the concentration of alcohol in the fuel. For example, a 10% v/v ethanol blend with a typical hydrocarbon mixture at room temperature can dissolve up to 0.5% v/v water.

The calorific value and the air fuel ratio of the ethanol gasoline blend decrease, but this decrease is much lower than the content of ethanol added (i.e. 8-9% of calorific value and 11-12% v/v of air fuel ratio decrease with the addition of 30% v/v ethanol).

No anions and cations were found in any country. Methyl tert-butyl ether (MTBE) was found only in Chile.

Ethanol addition significantly increases octane number, which is beneficial, especially for the efficient use of modern vehicles. In many studied cases, octane number goes up to or around 100. For existent fleets in most countries, RON 95 gasoline is adequate for vehicle technology; however, according to the Worldwide Fuel Charter (WWFC) category 6 gasoline specifications[1], a minimum RON of 98-102 should be achieved to fulfill future or anticipated U.S. light-duty vehicle GHG and fuel economy standards and future EU targets for CO_2. This category is intended to enable the introduction of engines and vehicles with higher fuel efficiency and lower exhaust emissions.

Moreover, adding ethanol in volumes higher than 15% v/v would keep RVP at regulatory levels, as its peak is reached at 10-15% v/v and then starts decreasing. This is why it is beneficial to blend ethanol above 10-15%v/v as it would affect RVP positively.

[1] https://www.acea.auto/files/WWFC_19_gasoline_diesel.pdf

SECTION 1: COUNTRY PROFILES: REGULATIONS, GASOLINES AND BLENDSTOCKS

To understand the blendstock composition of gasoline is a difficult task. This is because all refineries are different owing to their different unit configurations and capacities, physical locations, and economic drivers. Furthermore, 70% of total final gasoline consumed worldwide is blended in terminals and only 30% is distributed directly from refineries, according to SGS data. Blending is mainly performed in the main trading centers in the world, which are Europe (The Netherlands and Belgium and to a lesser extent in France, Italy, and Spain), Asia (UAE, Dubai) and the U.S. (Houston).

Gasoline suppliers usually run one to six grades simultaneously and each batch of the gasoline's blendstock always differ. The deciding factors on what blending components are used for gasoline's production are usually: the availability of the components, its price on the day of the supply of the blendstocks and that it meets the specifications.

Major components used in gasoline production are:

- Alkylates
- Pyrolysis gasoline
- Catalytic gasoline
- Reformates
- Isomerates
- Naphthas
- Raffinates
- Butanes
- In some countries, natural gasolines/condensates
- Chemical mixtures such as mixed xylenes, mixed hydrocarbons with 4-9 carbon atoms such as pentanes, hexanes, etc.

Gasoline is usually a blend of a specific base gasoline and other components. The main bases, which have a greater volume in the final blendstock, are usually reformate and catalytic gasoline. The most used components that increase octane in the mix are isomerates, alkylates and butanes. The other components, such as raffinates, pentanes, hexanes, and other petrochemical gasolines, are used in a smaller share in gasoline blendstocks.

In the refineries, from the light distillation products, butane (nC4) is typically blended into gasoline because it boosts octane, as mentioned above, but due to its high Reid Vapor Pressure (RVP) the amount that can be blended is limited, particularly during the lower RVP[2] summer season. Therefore, summer gasoline blends typically contain less nC4 than winter blends.

When FCC naphtha(s) are blended to gasoline, desulfurization may be required. The desulfurization process typically results in a loss of RON anywhere between one to five octane numbers, which in turn requires blending with high octane blendstocks. Hydrocracking units produce naphtha(s) that can be blended directly into gasoline or sent to other units for further upgrading before blending. The isomerization unit rearranges atoms within naphtha molecules to produce molecules with higher octane ratings, but it also increases RVP, limiting the use of isomerization units in increasing the octane ratings of finished gasoline. Reformers remove hydrogen atoms

[2] The value of Reid Vapor Pressure (RVP) in gasoline should be controlled, particularly in summer, because it can potentially increase the formation of smog and volatile organic compounds (VOC).

and rearrange the hydrocarbon molecules, to form “aromatic” molecules including benzene, toluene, and xylenes. These aromatics have high octane ratings when used in gasoline and are also used as petrochemical feedstocks. Isomerization units increase octane ratings of light straight run (LSR).

Figure 2 summarizes the gasoline blending components that are produced in petroleum refineries and their main characteristics. The highest-octane blending components are alkylates, reformates, and nC4. Both alkylate and reformate have relatively low RVPs, making them excellent blending components.

Figure 2: Refinery produced gasoline components

Component	Process Unit Source	AKI (RON + MON)/2	RVP psi	Sulfur mg/kg	Aromatics (% v/v)	Olefins (% v/v)	Limiting gasoline specification
Normal butane	Distillation	90 to 92	70 to 74	2 to 6	0	1	RVP, V/L
Light straight run naphtha	Crude Distillation	60 to 66	10 to 13	10 to 500+	8	10	Octane, RVP, V/L
Heavy naphtha (non-hydrotreated)	Crude Distillation, Coker, Hydrocracker	58 to 64	1 to 1.5	40 to 500+	38	20	Octane, sulfur
Reformate	Reformer	85 to 87	2 to 3	2 to 6	50	0	DI, T50, Benzene
FCC gasoline (non-hydrotreated)	FCC	82 to 87	1 to 2	10 to 500+	27	25	Sulfur (if untreated)
Alkylate	Alkylation Unit	90 to 96	4 to 5	5 to 15	0	0	None
Isomerate	Isomerization Unit	78 to 83	7.8 to 8.5	1 to 10	0	0	RVP
Ethanol	N/A	110 to 120	Increase of 1 psi for 10-20% v/v blend	0	0	0	RVP

Source: U.S. Energy Information Administration (EIA), Transport Energy Strategies, 2021

Many Latin American countries do not produce enough refined products to satisfy the demand for gasoline, despite of the high number of refineries in the region, as listed below.

Figure 3: Latin American refineries capacity (million liters per day)

México	
Cadereyta	43.72
Madero	30.21
Minantitlan	38.16
Salamanca	39.75
Salina Cruz	52.47
Tula	50.08
Total	254.38

Argentina	
Bahía Blanca	4.9
Buenos aires	17.5
Campana	13.8
Campo Durán	5.1
La Plata	32.8
Luján de Cuyo	17.5
Plaza Huincul	4.0
San Lorenzo	7.9
Total	103.5

Colombia	
Barrancabermeja	36.9
Orito	1.0
Reficar	26.2
Total	64.1

Chile	
Aconcagua	16.5
BioBio	18.4
Gregorio	2.5
Total	37.5

Peru	
Conchan	2.5
Iquitos	1.9
La Pampillas	18.6
Pucallpa	0.6
Talara	9.9
Total	33.5

Ecuador	
Esmeraldas	17.5
La Libertad	7.3
Shushufindi	3.2
Total	28.0

Bolivia	
Cochabamba	6.5
Santa Cruz de la Sierra	3.2
Total	9.7

Dominican Republic	
Bonao	2.5
Haina	5.4
Total	7.9

Uruguay	
La Teja Montevideo	7.9

Jamaica	
Kingston	5.7

Costa Rica	
Limon	4.0

Nicaragua	
Managua	3.2

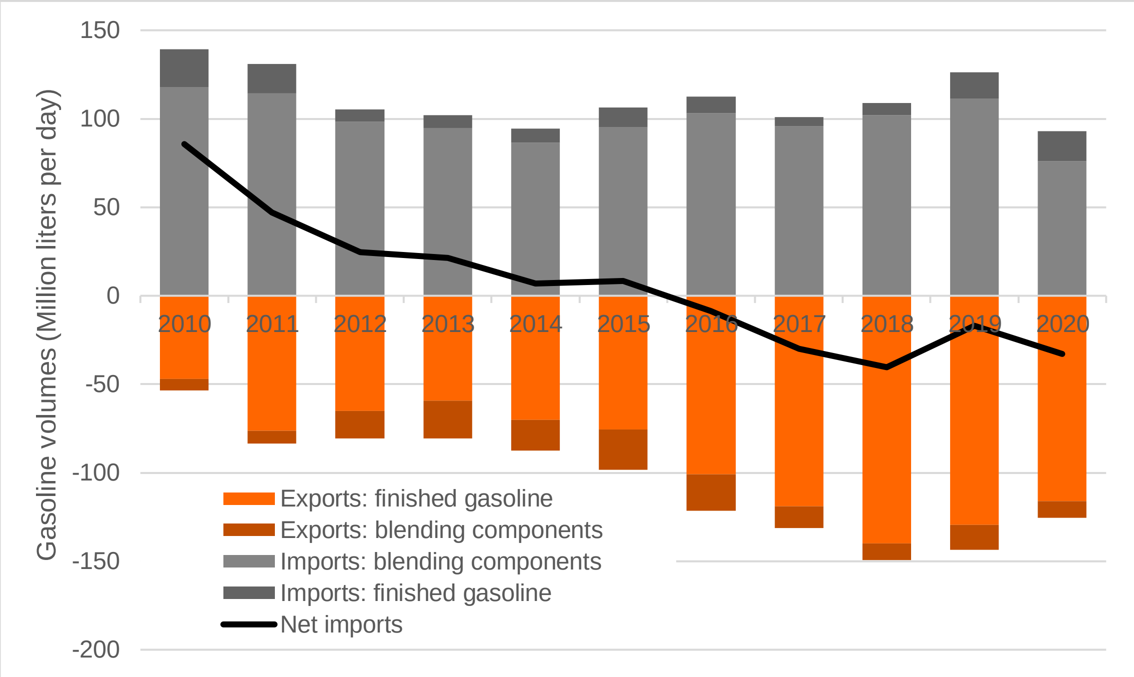
Source: HCX

As a result, the countries rely on imports of fuels. A large part of Central America, the Caribbean, and some South American countries import finished gasoline or gasoline blending components from the U.S. that is one of the major gasoline exporters globally. The most exported product from the U.S. to Latin American countries is conventional gasoline.

In 2020, the U.S. exported 106.20 million liters per day of finished motor gasoline from the Gulf Coast (PAD III)[3] and across the Atlantic Ocean to other regions of the world, of which 65.2 million liters per day were exported to Mexico and 37 million liters per day to other Latin American Countries.

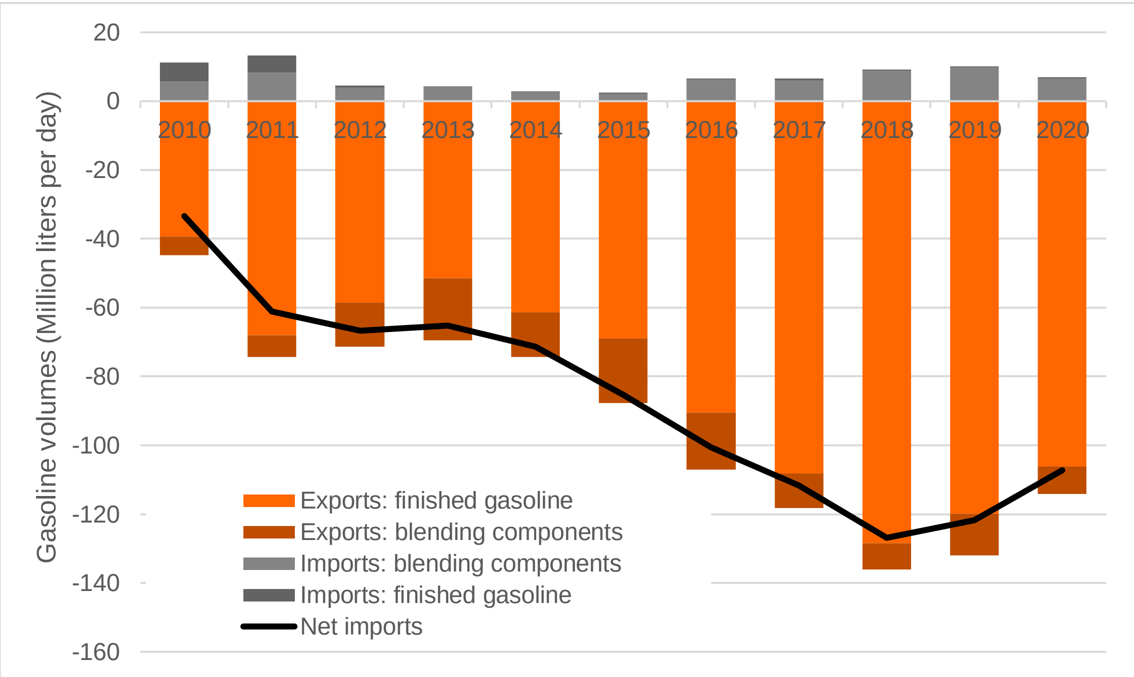
[3] The North Coast of the Gulf of Mexico (PADD III) region is a reference market for commercial transactions, due to its importance in the domestic trade of the United States and in the markets of the Atlantic Ocean.

Figure 4: Gasoline exports from United States



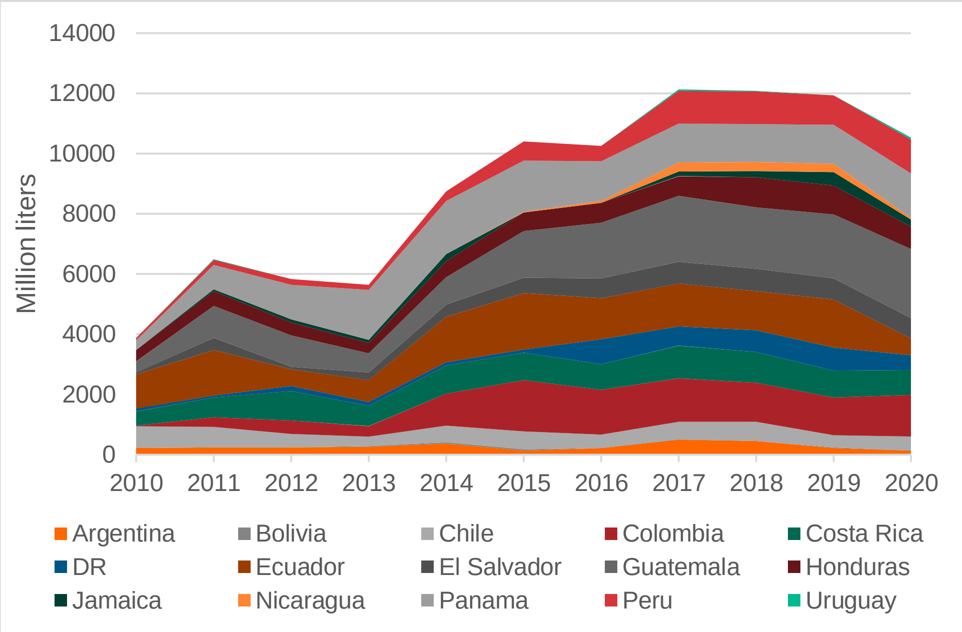
Source: EIA, SGS INSPIRE Compilation

Figure 5: Gasoline exports from the Gulf Coast of the United States (PADD III)



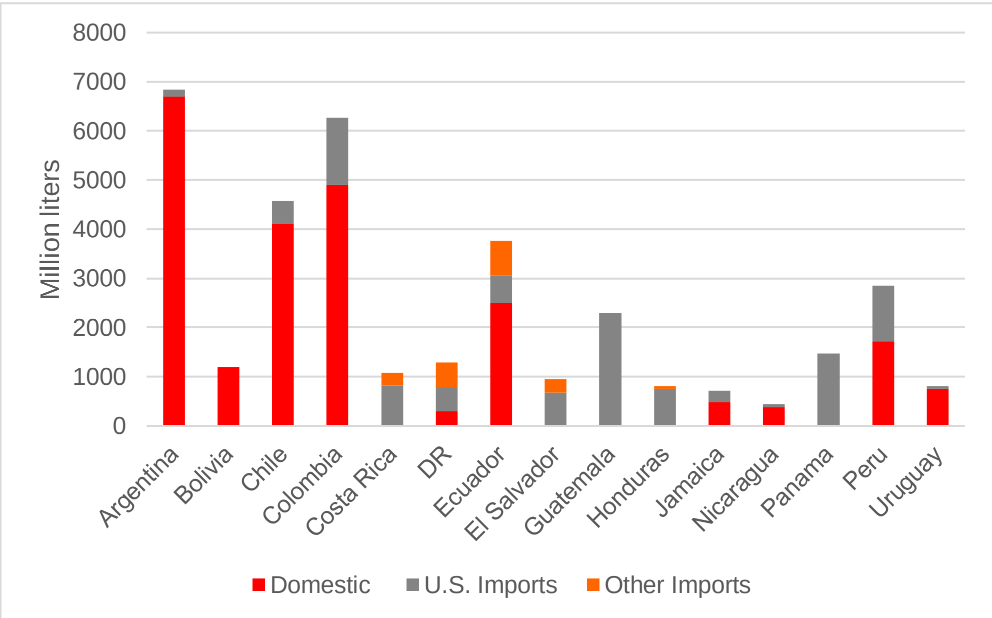
Source: HCX with EIA data

Figure 6: U.S. gasoline exports to Latin American countries (except Mexico)



Source: EIA, SGS INSPIRE Compilation

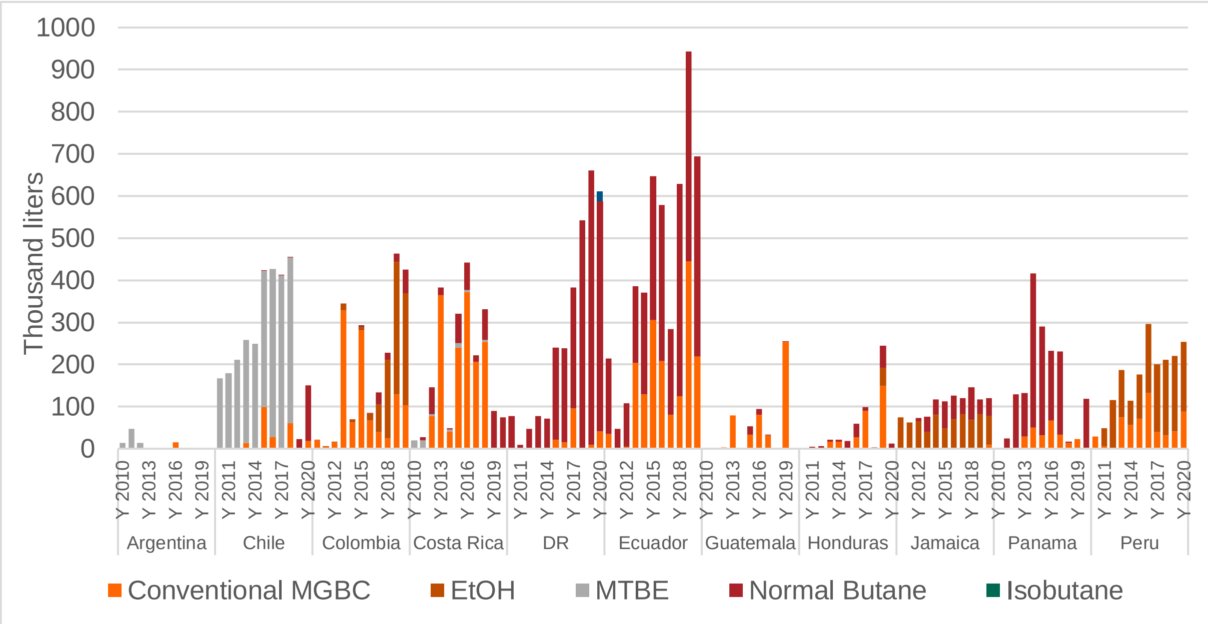
Figure 7: Source of origin of gasoline consumption in Latin America (except Mexico) in 2020



Source: Domestic sources, EIA, SGS INSPIRE Compilation

Most countries import gasoline components such as motor conventional gasoline blendstock (MGBC), butane, ethanol, and MTBE. Ethanol is imported by Colombia, Jamaica, and Peru. Butane is imported by Dominican Republic, Ecuador, Panama and in lower quantities by Jamaica.

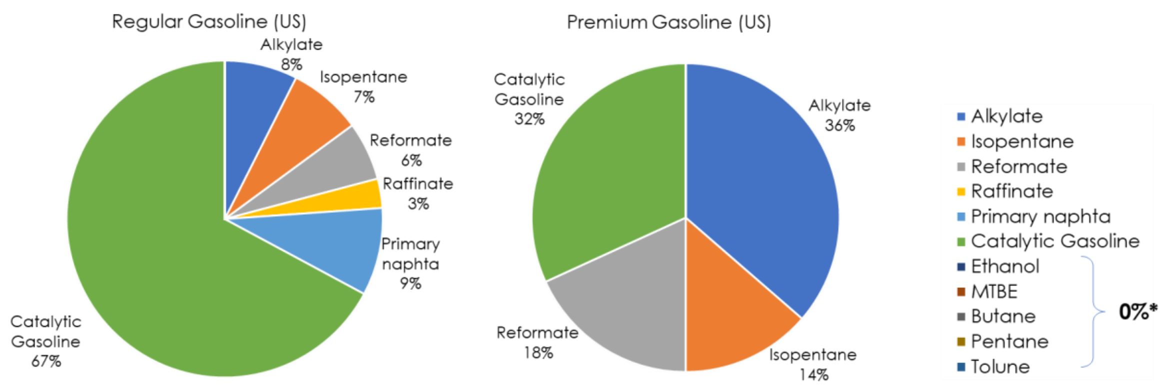
Figure 8: U.S. Exports of blendstocks to Latin American countries



Source: U.S. EIA, SGS INSPIRE Compilation

For the purposes of this study, we will consider both gasoline blendstocks produced in Latin American refineries and gasoline blendstocks originating from the U.S., as well as finished gasoline exported to Latin America from the U.S. In general, exported gasoline blendstocks from the U.S. have similar composition and formulation as other gasolines in the market, but may vary on octane number.

Figure 9: Gasoline blending components in the United States



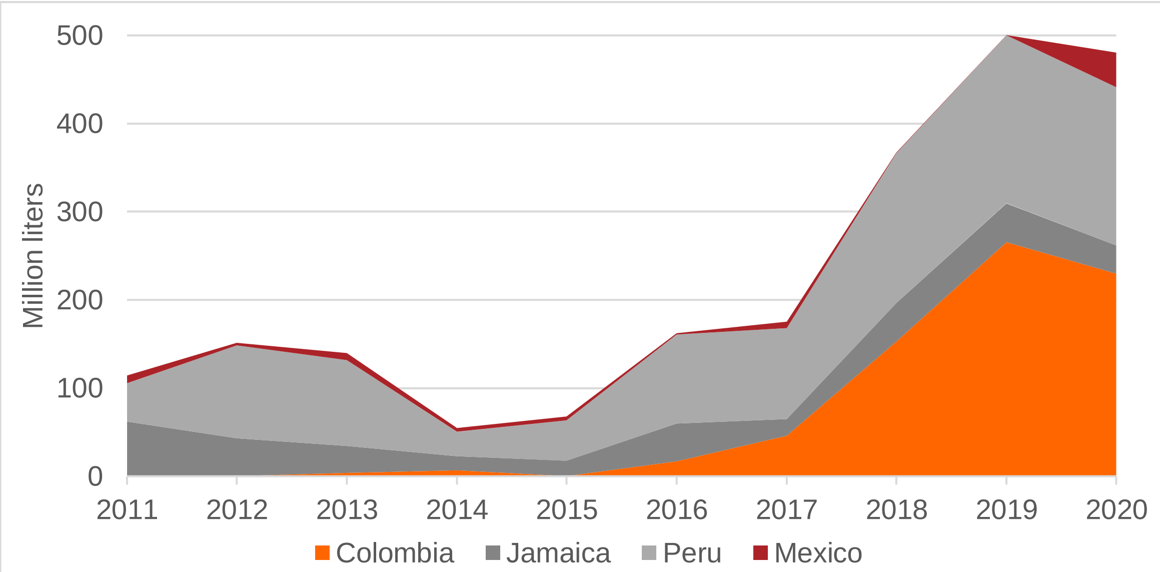
Typical Regular and Premium gasoline from the US, produced in Merey Sweeney Refinery from Texas.

* Some components are not presented in the example but may be blending components in other gasoline from other countries and other refineries.

Source: HCX

Ethanol is added to gasoline blendstocks in many parts of the world for various reasons. This renewable fuel, made from biomass, boosts octane, reduces sulfur and hydrocarbons from the blendstock mix, and is used to meet biofuel policy targets. Several Latin American countries have well-established domestic ethanol industries, however, imports of U.S. ethanol to the region are also significant, and are growing, as shown in the graph below. The countries with higher ethanol imports from the U.S. have been traditionally Peru and Jamaica, but lately Colombia has surpassed both. Ethanol imports decreased in all countries in 2020, due to the reduced transport demand caused by COVID-19 pandemic, except in Mexico. For the purposes of the analysis, the HS Code 220720 (Ethyl alcohol and other spirits; denatured, of any strength) has been used, as fuel ethanol is denatured. Argentina, Dominican Republic, Mexico, Costa Rica, and Chile have imported small quantities of fuel ethanol over the years; always less than 1 million liters per year per country.

Figure 10: Denatured fuel ethanol imports from U.S. to Latin America per country



Source: Worldbank, U.S. Renewable Fuel Association, United Nations Comtrade, U.S. Department of Agriculture

The sources consulted for this analysis have been national administration or industry sources, United Nations Comtrade, Worldbank, U.S. Department of Agriculture, U.S. EIA, and U.S. Renewable Fuel Association.

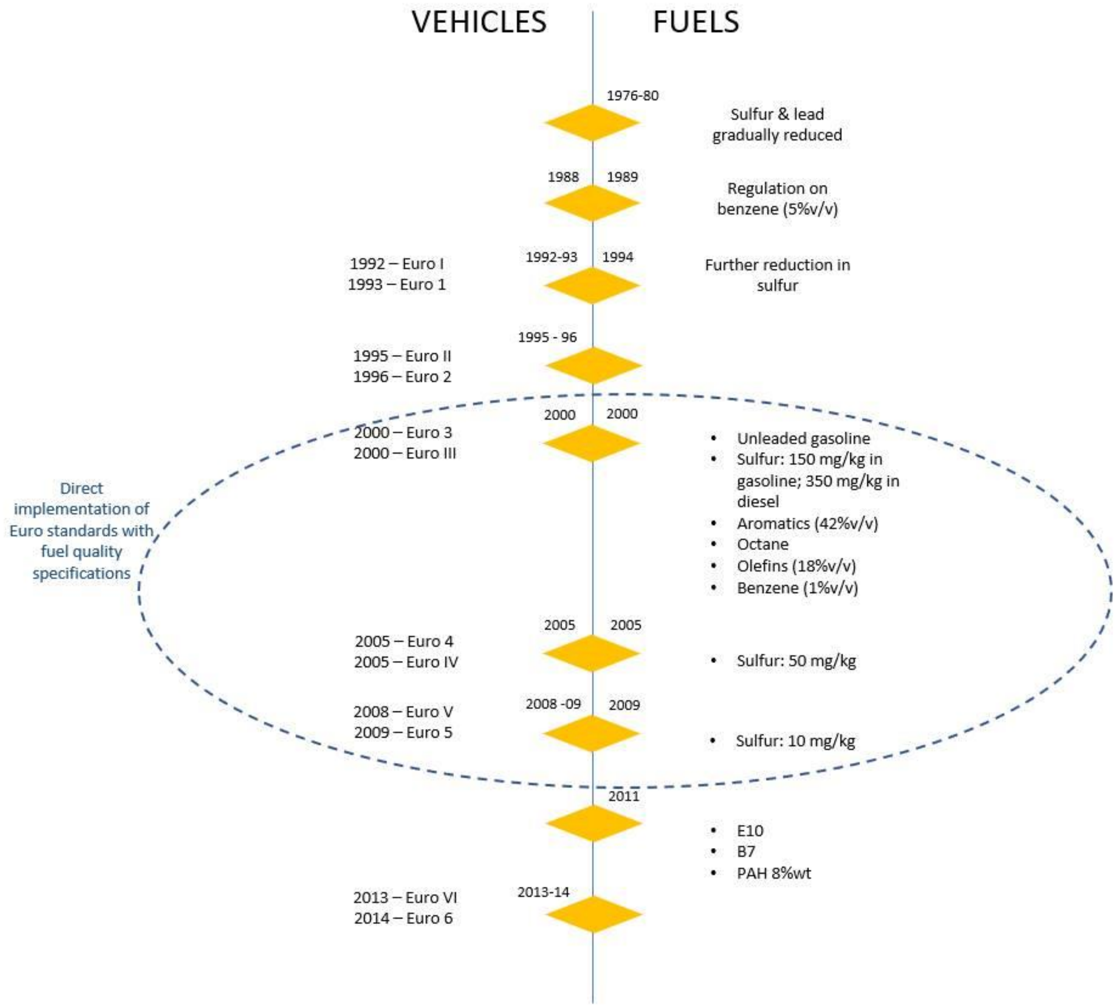
KEY TAKEAWAYS

This section analyzes the fifteen chosen countries from four different points of view:

- Regulations: showing historic and current gasoline and ethanol laws and specifications
- Current fuel quality standards and objectives: this section compares national fuel standards with Euro-enabling reference standards and indicates which Euro-enabling gasoline standard is implemented in each country. Vehicle emissions standards are also specified. The specifications implemented by the consecutive European Directives to improve fuel quality were aligned by stricter vehicle emissions standards
- Comparison against standard: domestic specifications are compared with Euro 6 enabling fuel quality specifications. When data about actual fuel quality on the market, compiled by SGS on the basis of samples taken from fuel stations, exists, this data is also compared with specifications to see whether gasoline meets the regulation
- Blendstocks analysis: analyzing gasoline production, imports, and refinery stocks, an average blending components mix is added for each country

This table indicates European Directives, their correspondent Euro enabling standard.

Figure 11: Euro fuel quality enabling and vehicle emissions standards



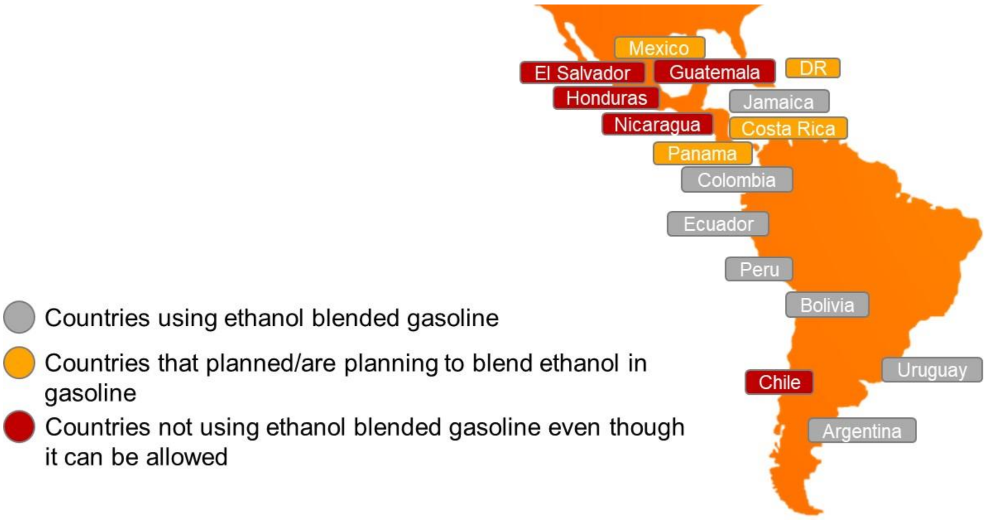
Source: SGS

As can be seen in this section, many Latin American countries have well-established ethanol industries, and many countries, particularly in South America, blend ethanol as required in regulatory blending mandates. Most countries have ethanol specifications, and the ethanol blended into gasoline must fulfill these specifications. Some countries, even though they have domestic ethanol production, must import ethanol from third countries, as it was described in the previous section; this is the case of Colombia, Peru, Jamaica and lately Mexico.

There are countries that do not blend ethanol, but have potential to do it, as Chile or some Central American countries.

Figure 12 shows the use or absence of ethanol blended in gasoline per country in the region, and Figure 13 compares fuel quality and vehicle exhaust emissions standards and the use of ethanol per country.

Figure 12: Use of ethanol per country in Latin America



Source: SGS INSPIRE Compilation

Figure 13: Comparison of fuel and vehicle exhaust emissions standards and ethanol use in Latin America

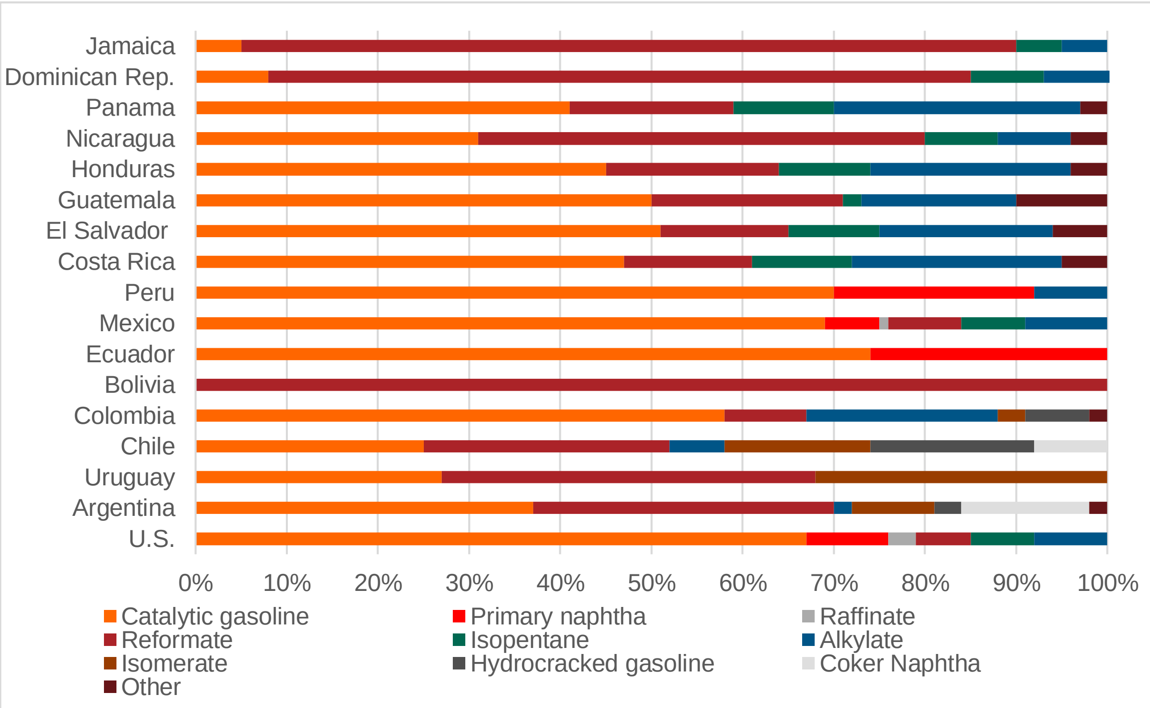
Country	Fuel quality enabling Euro standard	Vehicle exhaust emission standard	Ethanol blend mandate/allowed
Mexico	Euro 3-4	Euro IV	E5.8 allowed (not frequently used)
Guatemala	Euro 2	N/A	E10 (not used)
El Salvador	Euro 2	N/A	E0
Honduras	Euro 2	N/A	E0
Nicaragua	Euro 2	N/A	E0
Costa Rica	Euro 4	Euro 6	E10 allowed (not used)
Panama	Euro 3	N/A	E10 (not used)
Jamaica	Euro 0	N/A	E10
DR	Euro 0	N/A	E10 allowed (not used)
Colombia	Euro 2	Euro 2/I-IV	E10/E0
Ecuador	Euro 2	Euro 3/I	E10 allowed (E5 and E0 used)
Peru	Euro 1-4	Euro 4/IV	E7.8
Bolivia	Euro 2	Euro 2/III	E12 in one grade/E0
Uruguay	Euro 5/6	Euro III	E10
Argentina	Euro 3/Euro 5	Euro 5/V	E12
Chile	Euro 5	Euro 5/V	E5 (not used)

Source: SGS INSPIRE Compilation

Specifications for each country are compared to the latest EU specifications, and when available, actual fuel quality in the country. The conclusion of this analysis is that gasoline in the region complies with domestic specifications, except for the content of ethanol in the countries with a blending mandate. In the comparison of EU specifications, octane and sulfur are the parameters with a higher number of non-compliances.

As for the blending components in gasoline used in the region, the two blendstocks used the most are catalytic gasoline and reformate. Argentina, Chile, Colombia, and Mexico produce also other blending components because they have more complex refineries. The mix of gasoline blendstocks used to produce gasoline in the Latin American countries (and the U.S.) is depictured in Figure 14 and described in the section below. It considers domestic production and imports.

Figure 14: Mix of gasoline blendstocks used in Latin America and the U.S.



Source: SGS INSPIRE Compilation

ARGENTINA

REGULATIONS

Gasoline

Current gasoline specifications are defined in Resolution 5/2016 from May 31, 2016, which supersedes Resolution 1283/2006 from September 6, 2006, and Resolution 478/2009 from June 5, 2009. Resolution 5/2016 also sets a plan to reduce sulfur limits of gasoline in the period of 2019-2022. Resolution 558/2019 and Resolution 576/2019 modified the plan delaying the sulfur reduction implementation date of gasoline grade 2 since domestic refineries could not meet the timelines of the plan.

Currently there are two gasoline grades on the market:

- Gasoline grade 2 or regular
- Gasoline grade 3 or premium

Before 2016 there was another gasoline grade in Argentina: gasoline grade 1, with sulfur content of 500 mg/kg which was higher compared with sulfur limits in grade 2 and grade 3. Resolution 1283/2006 established that supply of gasoline grade 1 was optional as of 2009, and divided gasoline grade 2 between high-density and low-density zones gasoline. This classification depended on the population of cities and provinces. This division was removed in Resolution 478/2009.

Reid vapor pressure (RVP) values depend on geographical zones and seasons.

Figure 15: Enforced sulfur reduction implementation dates and sulfur content (mg/kg)

Gasoline Grade	Resolution 478/2009		Resolution 5/2016			Resolution 558/2019 and Resolution 576/2019
Implementation years	2009	2012	2016	2019	2022	2024
Grade 1	Optional supply		Not supplied			
Grade 2		150	150		50	50
Grade 3	150	50	50	10		

Source: Resolution 1283, 2006, SGS INSPIRE Compilation

In 2011, Resolution 188 reduced the allowed manganese content in gasoline from 18 mg/l to 8.3 mg/l, and Resolution 5/2016 further decreased it to 2.5 mg/l.

Ethanol

Ethanol (E100) is not used as a neat fuel, but it is blended with gasoline up to 12% v/v. Resolution 450/2013 defines ethanol specifications in Argentina, as well as the maximum content of oxygenated compounds in gasoline. This regulation was superseded by Resolution 37/206 which amended the maximum content of oxygenated compounds of gasoline. The limits for oxygenates in Argentina are 2.5 mg/l for manganese, 15% v/v for MTBE and 22% v/v for total ethers.

Figure 16: Maximum content of oxygenated compounds according to Resolution 37/2016

Product	Max. level (% v/v.)
MTBE (methyl tert-butyl ether)	15
Ethanol	12[1]
Ethers with 6 or more C atoms	22

1. This limit has a tolerance of 2% v/v.

Source: Resolution 37/2016, SGS INSPIRE Compilation

Ethanol blending in Argentina started with the policy that implemented the ethanol mandate, which began in 2010 according to Law 26.093/2006.

Law 26.334 was implemented in January 2008 with the aim of promoting the production of ethanol from sugarcane. This law allowed sugar mills to participate under the biofuel promotional regime, under the conditions that they maintain the basic norms and regulations of the biofuel law.

This Law has been superseded by Law 27.640, published on August 4, 2021, approving a new regulatory framework for biofuels in Argentina. It will be valid until December 31, 2030, but the government will be able to extend it one single time for five more years, until December 31, 2035. The new law maintains the ethanol blend mandate at 12% v/v, 6% v/v for corn-based ethanol and 6% v/v for sugarcane based ethanol.

Figure 17: Ethanol blend mandates in Argentina

Piece of legislation	Date of implementation	Volume mandate (% v/v)
Law 26093 of 2006	April 2010	5
Resolution 44/2014	September 2014	8.5
Resolution 44/2014	October 2014	9
Resolution 44/2014	November 2014	9.5
Resolution 44/2014	December 2014	10
Resolution 37/2016	April 2016	12
Law 27640 of 2021	August 2021	12

Source: SGS INSPIRE Compilation

CURRENT FUEL QUALITY STANDARDS AND OBJECTIVES

As mentioned above, Argentina has two gasoline grades on the market: grade 2 and grade 3. Grade 2 is similar to Euro 3 enabling specifications, and grade 3 is similar to Euro 5 enabling specifications. Not all properties are the same as European specifications, this comparison is mostly based on sulfur limits.

Furthermore, vehicle emissions standards in place are Euro 5 for light-duty vehicles and Euro V for heavy-duty vehicles.

COMPARISON AGAINST STANDARDS

Specifications of gasoline in Argentina are quite different from European specifications enabling Euro 6 that currently apply in the EU. However, actual quality meets EU specifications except for sulfur in grade 2 and MON in both grades. With respect to Argentinean specifications, ethanol content is below the 12% v/v blend mandate.

The following table gives an overview of this comparison about the main properties.

Actual quality shown in the table is the average of values of 10 samples obtained in Buenos Aires and Comodoro Rivadavia, 6 samples of grade 2 and 4 samples of grade 3.

Figure 18: Comparison between Argentinean and EU specifications and Argentinean actual gasoline quality in 2020

	Argentina						**Gasoline actual quality Winter 2020 Average**		**EU**			
Applicability	North Zone		Central Zone		South Zone		Survey performed by SGS in limited number of stations across the country		All countries			
Implementation Date	2019						2020/2021		2017			
Selected Grade	Gasoline Grade 2	Gasoline Grade 3	Gasoline Grade 2	Gasoline Grade 3	Gasoline Grade 2	Gasoline Grade 3	Grade 2	Grade 3	RON 95 E5	RON 95 E10	RON 98 E5	RON 98 E10
Name	Resolution 5/2016 and Resolution 558/2019						Average values		EN 228:2012 + A1:2017 (Euro 6 enabling)			
Benzene Content	< 1 %v/v						0.51% v/v		< 1 %v/v			
Aromatics	< 40 %v/v						28.6% v/v		< 35 %v/v			
Olefins	-						13.1% v/v		< 18 %v/v			
Lead Content	< 5 mg/l						< 2.5 mg/l		< 5 mg/l			
Manganese	< 2.5 mg/l						< 0.1 mg/l		< 2.0 mg/l			
RON	> 93	> 97	> 93	> 97	> 93	> 97	96.3	98.6	> 95	> 95	> 98	> 98
MON	> 83	> 85	> 83	> 85	> 83	> 85	**84.3**	**87.5**	> 85	> 88	> 85	> 88
Sulfur Content	< 150 mg/kg	< 10 mg/kg	< 150 mg/kg	< 10 mg/kg	< 150 mg/kg	< 10 mg/kg	**74.3 mg/kg**	5.2 mg/kg	< 10 mg/kg			
Oxygen Content	< 4.5 %m/m						-		< 2.7 %m/m	< 3.7 %m/m	< 2.7 %m/m	< 3.7 %m/m
Ethanol (EtOH)	<> 12 - 14 %v/v						**11.6% v/v**		< 5 %v/v	< 10 %v/v	< 5 %v/v	< 10 %v/v
RVP 37.8°C (Summer)	<> 35 - 70 kPa				<> 45 - 80 kPa		-		<> 60 - 70 kPa *Depends on the country, RVP is regulated in the EU Fuel Quality Directive			
RVP 37.8°C (Winter)	<> 45 - 80 kPa		<> 55 - 90 kPa				65	65.3				
RVP 37.8°C (Transition)			<> 45 - 80 kPa				-					
MTBE	< 15 %v/v						2.54% v/v		-			
Ethers 5 or more C Atoms	< 22 %v/v						2.54% v/v		Based on oxygen content	< 22 %v/v	Based on oxygen content	< 22 %v/v

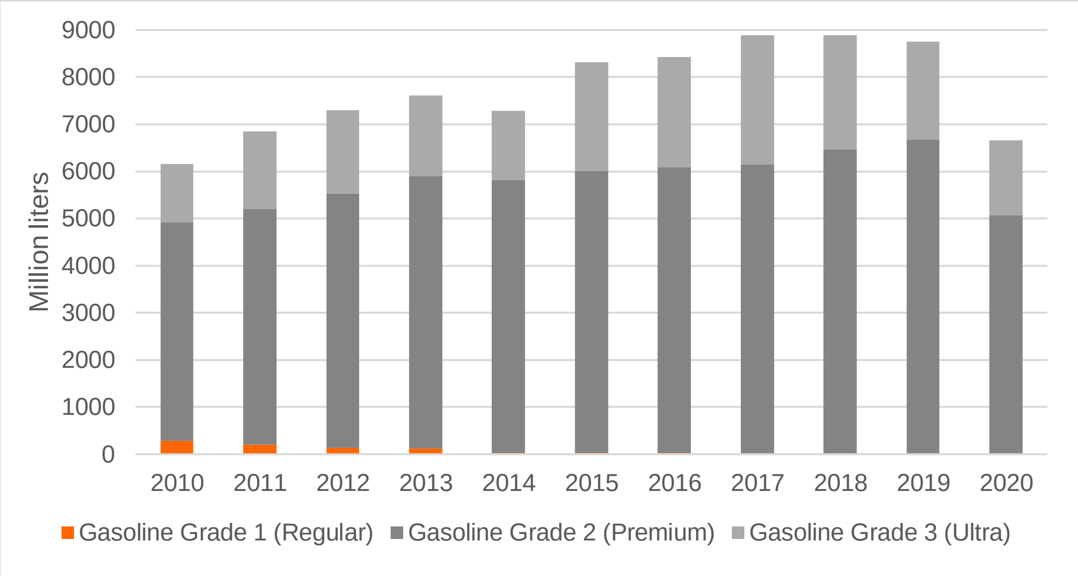
*In orange the values that would not comply with EU specifications and in blue the values that do not comply with Argentinean specifications.

Source: Argentinean and EU specifications, SGS Worldwide Fuel Survey, 2021

BLENDSTOCK ANALYSIS

Production of total gasoline in Argentina is about 9,000 million liters per year, with a rate of approximately 20% of gasoline grade 3 (RON 97) and 80% gasoline grade 2 (RON 93). In 2020, overall gasoline production decreased 20% with respect to 2019. Gasoline grade 1 stopped being produced in 2014.

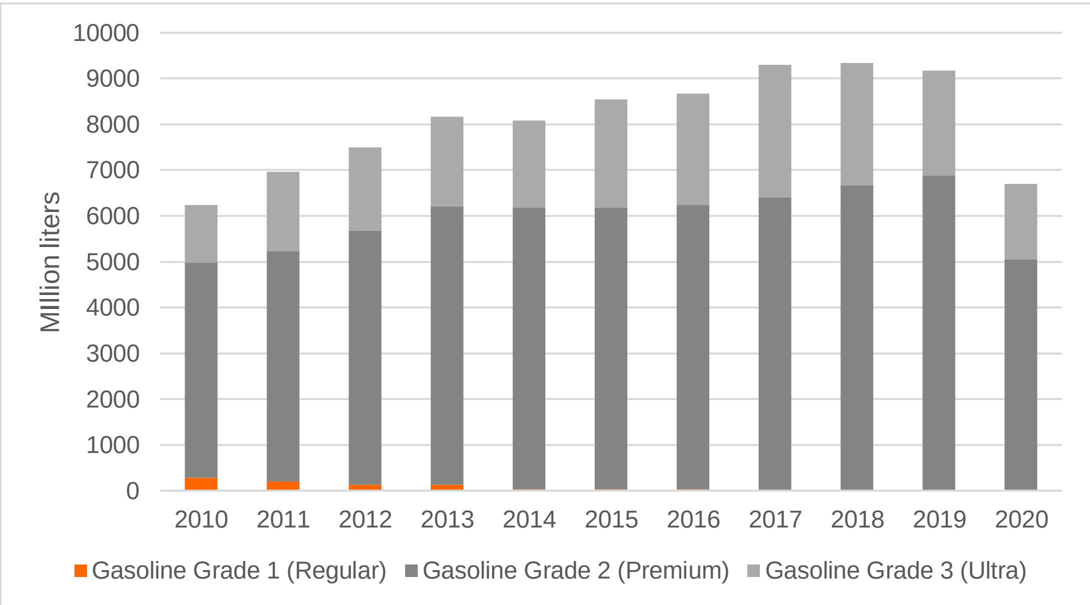
Figure 19: Gasoline production in Argentina per octane grade



Source: Secretary of Energy, SGS INSPIRE Compilation

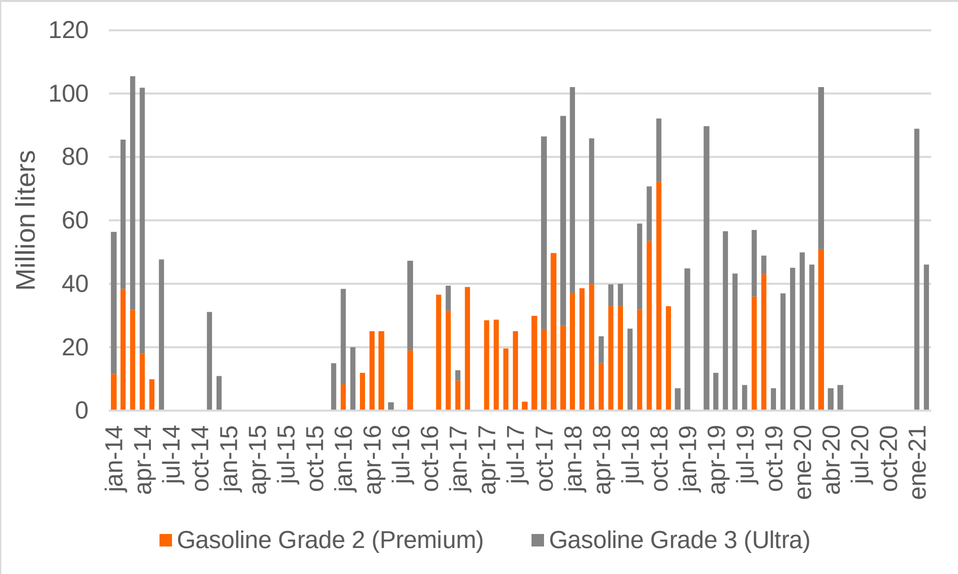
Gasoline demand is somewhat higher than gasoline supply, as shown in Figure 20. The trend is approximately 5% higher, resulting in low gasoline imports, depicted in Figure 21.

Figure 20: Gasoline demand in Argentina per octane grade



Source: Secretary of Energy, SGS INSPIRE Compilation

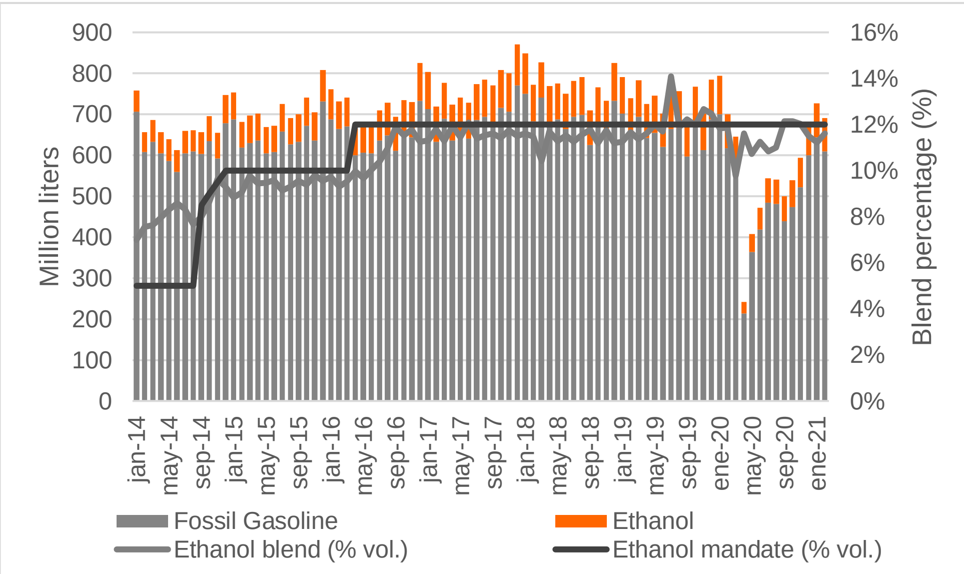
Figure 21: Gasoline imports to Argentina, 2014-2021



Source: Secretary of Energy, SGS INSPIRE Compilation

The following figure shows the volume of ethanol blended in gasoline since 2014. It can be observed that the ethanol volume blended in gasoline has corresponded to the ethanol blend mandate in Argentina, except when the blend mandate increased from E10 to E12. The switch happened officially in April 2016 but due to a lack of domestic ethanol until October 2016, the mandate was not fulfilled until that time and the blending was kept at the level of 10% v/v.

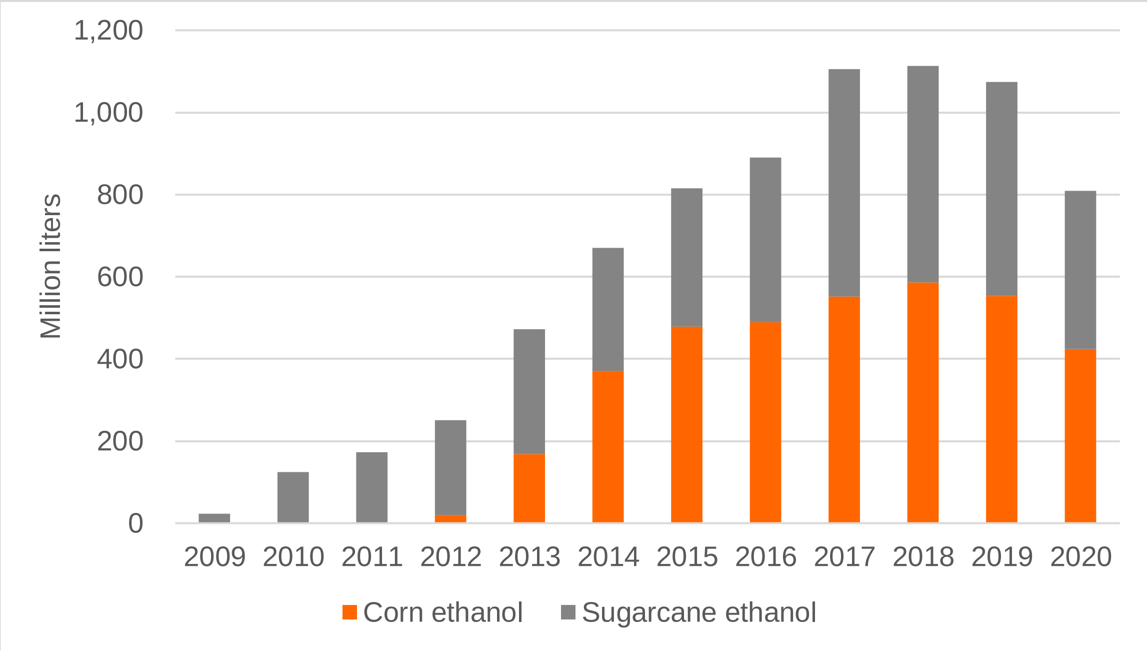
Figure 22: Ethanol blended in gasoline in Argentina, 2014-2021



Source: Ministry of Energy and Mining, Secretary of Energy, SGS INSPIRE Compilation

There are nineteen ethanol plants in Argentina, with a total production capacity of 1.4 billion liters. Thirteen plants use sugarcane as feedstock and six use corn. Decree 543/2016 encourages ethanol suppliers to achieve balanced feedstock utilization rate (50% sugarcane-based ethanol and 50% corn-based ethanol) which appears to be successfully attained, as visible in the following figure.

Figure 23: Ethanol production and consumption in Argentina, 2009-2020



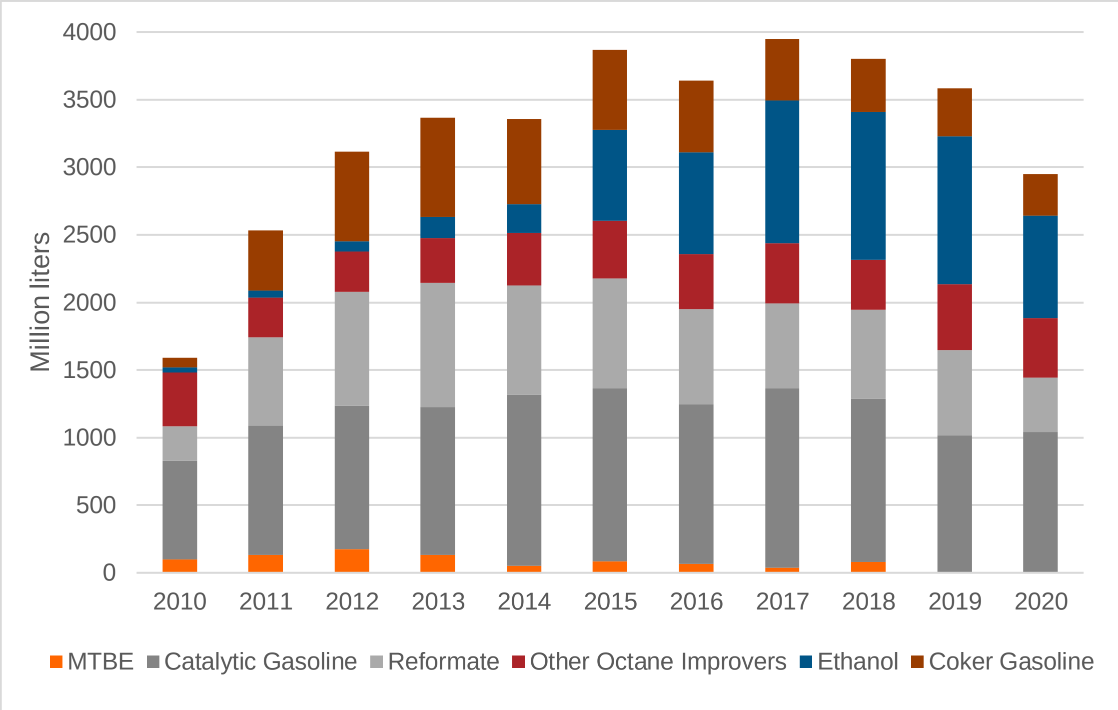
Source: Secretary of Energy, SGS INSPIRE Compilation

There is almost no ethanol trade in Argentina, therefore production is virtually the same as consumption.

Data extracted from the SGS Shipping On-line (SOL) service indicates that 792 million liters were traded to Argentina from April 2020 to April 2021. From this amount, 774 million liters were finished gasoline and only 18 million liters were regular gasoline blendstocks. The largest cargoes were shipped to the Axion Energy Terminal and the Tegral terminal. The countries exporting gasoline to Argentina were United States, Brazil, and Gibraltar (European countries), according to SGS SOL. According to United Nations Comtrade, exports to Argentina come from United States, Belgium, Germany, and Spain in 2019. For these gasoline imports, Argentina is not likely the final destination.

Argentina has a significant refining capacity and complex refineries. In the next figure, the processed products in the Argentinean refineries used for gasoline production can be observed. As we can see, the main products used to produce gasoline are *catalytic gasoline* and *ethanol*, probably because of their price advantage over others.

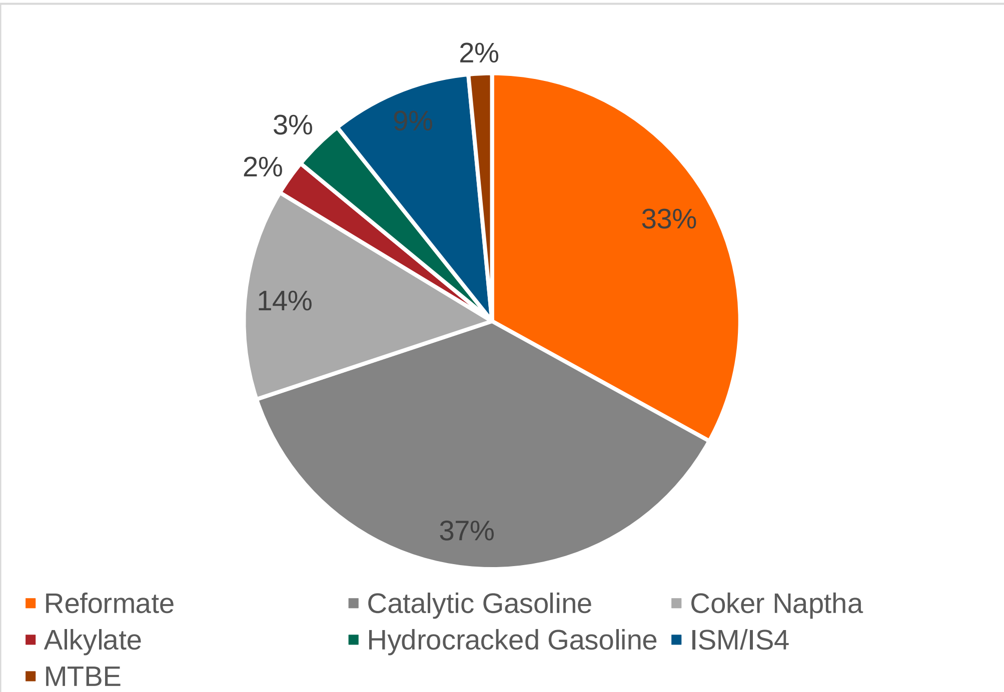
Figure 24: Processed products related to gasoline in Argentina, 2010-2020



Source: Secretary of Energy of Argentina, 2021

The data suggest that the produced gasoline blending components to produce gasoline in Argentina are as shown in Figure 25.

Figure 25: Gasoline blendstock mix in Argentina



Source: HCX with Wood Mackenzie PennEnergy Research and Oil and Gas Journal Data

BOLIVIA

REGULATIONS

Gasoline

The current gasoline specifications are defined in the Supreme Decree N° 2741 of the Ministry of Hydrocarbons and Energy, published on April 27, 2016.

Supreme Decree N° 2741 defines two grades of gasoline:

- Gasoline regular (in Spanish "gasolina especial"), with a minimum research octane number (RON) of 85
- Gasoline premium (in Spanish "gasolina premium"), with a minimum RON of 95

The maximum sulfur content for both grades is 500 mg/kg. The only differences between the specifications of the two grades are the minimum RON and the maximum aromatics content, all the other limits being the same.

On November 17, 2017, the refiner YPFB introduced on the market a new grade of gasoline with RON 91, called in Spanish "gasolina Súper 91".

According to YPFB, the introduction of this grade was aimed at satisfying the demand of modern vehicles and diversifying the range of products in the country. Gasoline RON 91 was produced in the refinery Guillermo Elder Bell in Santa Cruz and was initially distributed in 12 gas stations in the city of Santa Cruz. On November 22, 2018, YPFB started supplying a new grade of gasoline with RON 92 and 12% v/v of ethanol (E12), called in Spanish "gasolina súper etanol 92". It was initially supplied in 6 gas stations in the department of La Paz. YPFB provides a map with the gas stations supplying gasoline RON 92. Other fuel suppliers also provide this grade of gasoline. The specifications of gasoline RON 92 were published on October 29, 2018 in Administrative Resolution RAR-ANH-DJ N° 0352-2018. The maximum sulfur content of this grade was set at 500 mg/kg.

The government announced in November 2018 that it is working towards the commercialization of a new grade of gasoline with RON 97. It is not known yet when this new grade will be commercialized.

In May 2019 Bolivia introduced a new gasoline grade in the market, gasoline special plus (Gasolina Especial Plus in Spanish), E8, with a minimum RON of 87. According to the ANH, the National Agency for Hydrocarbons in Bolivia, gasoline special plus (E8) is being supplied already in the areas of La Paz and Cochabamba and the intention of the ANH is to supply it nationwide, progressively replacing the regular grade.

Specifications of anhydrous ethanol are defined in the Ministerial Resolution N° 183-18 of December 28, 2018.

CURRENT FUEL QUALITY STANDARDS AND OBJECTIVES

Bolivia fuel quality specifications are similar to Euro 2 enabling specifications. Not all properties are the same as European specifications, this comparison is mostly done according to sulfur.

Furthermore, vehicle emissions standards in place are Euro 2 for light-duty vehicles and Euro III for heavy-duty vehicles.

COMPARISON AGAINST STANDARD

Figure 26 presents the comparison of Bolivian and EU specifications, and actual quality of gasoline in winter from 2019-2020. The differences between Bolivian and EU specifications are mostly related to octane. RON and MON are lower than in EU gasoline and manganese is used in Bolivia whereas it is not used in the EU. The aromatics limit is also higher in Bolivian specifications than in the EU. Sulfur content limit is much higher in Bolivia, but actual sulfur content in gasoline is near 10 mg/kg, showing a great improvement from past years.

The olefins content is significantly lower than required by specifications.

Actual quality shown in the table is the average values of 8 samples obtained in Santa Cruz and La Paz, 5 samples of regular and 3 samples of E12.

Figure 26: Comparison between Bolivian and EU specifications, Bolivian actual quality data

	Bolivia				**Bolivia actual gasoline Winter quality 2019/2020 Average**		**EU**			
Implementation Date	2016		2018	2019	N/A		2017			
Selected Grade	Gasoline Regular	Gasoline Premium	Gasoline for E8	Gasoline for E12	Regular	E12	RON 95 E5	RON 95 E10	RON 98 E5	RON 98 E10
Name	Supreme Decree 2741		Resolution 121-18	Resolution 042-19	Average values		EN 228:2012 + A1:2017 (Euro 6 enabling)			
Benzene Content	< 3 %v/v (2.7 %v/v for E12 in summer)				1.18% v/v		< 1 %v/v			
Aromatics	< 42 %v/v	< 48 %v/v	< 42 %v/v		20.9% v/v	22.1% v/v	< 35 %v/v			
Olefins	< 18 %v/v				3.6% v/v		< 18 %v/v			
Lead Content	< 0.013 g/l				< 2.5 mg/l		< 5 mg/l			
Manganese	< 18 mg/l				**6.8 mg/l**		< 2.0 mg/l			
RON	> 85	> 95	> 85	> 92	**88.1**	**92.9**	> 95	> 95	> 98	> 98
MON	-				-		> 85	> 88	> 85	> 88
Sulfur Content	< 500 mg/kg				**10.9 mg/kg**		< 10 mg/kg			
Oxygen Content	< 2.7 %m/m				-		< 2.7 %m/m	< 3.7 %m/m	< 2.7 %m/m	< 3.7 %m/m
Ethanol (EtOH)	-		< 8 %v/v	< 12 %v/v	**8.47% v/v**	13.31% v/v	< 5 %v/v	< 10 %v/v	< 5 %v/v	< 10 %v/v
RVP 37.8°C (Summer)	<> 48-79 kPa				69.9 kPa		<> 60 - 70 kPa *Depends on the country, RVP is regulated in the EU Fuel Quality Directive			
Ethers 5 or more C Atoms	-				0% v/v		Based on oxygen content	< 22 %v/v	Based on oxygen content	< 22 %v/v

*In orange the values that would not comply with EU specifications and in blue the values that do not comply with Bolivian specifications.

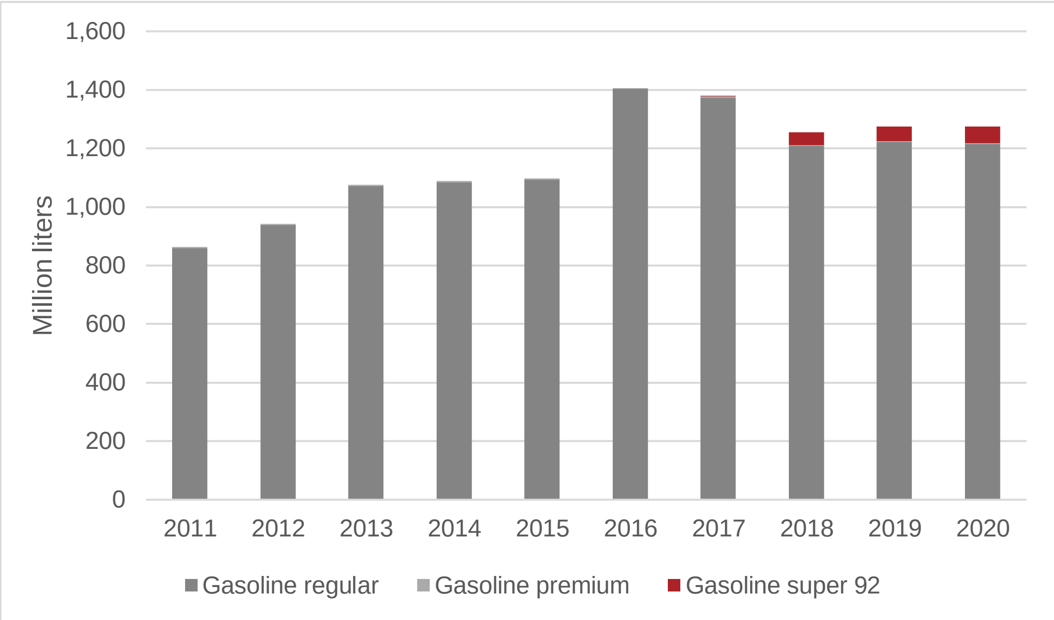
Source: Bolivian and EU specifications, SGS Worldwide Fuel Survey, 2021

BLENDSTOCK ANALYSIS

Production volumes of gasoline are shown in Figure 27. In 2020, gasoline regular amounted to 95.4% of the total gasoline produced, while gasoline premium amounted to 0.3% and gasoline E12 to 4.3%.

In 2020, local production amounted to almost all local consumption of gasoline.

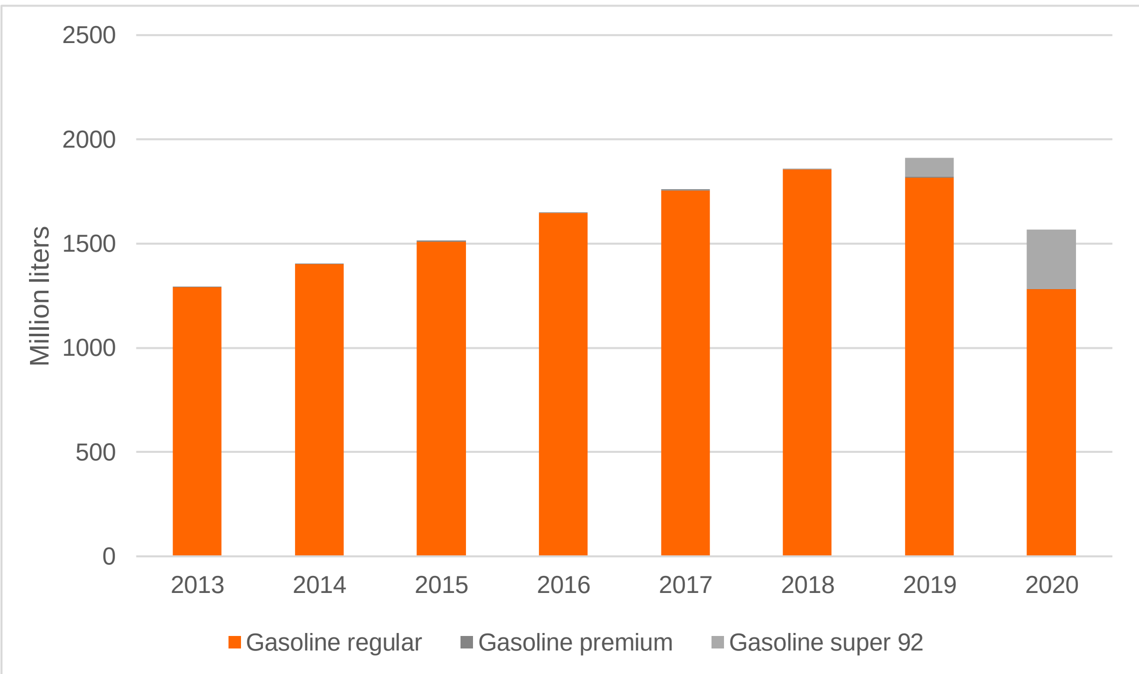
Figure 27: Production of gasoline in Bolivia



Source: ANH, 2021

The consumption volumes of gasoline in Bolivia are shown in Figure 28. Premium gasoline is barely used, while consumption of E12 gasoline started in 2019 and tripled in 2020.

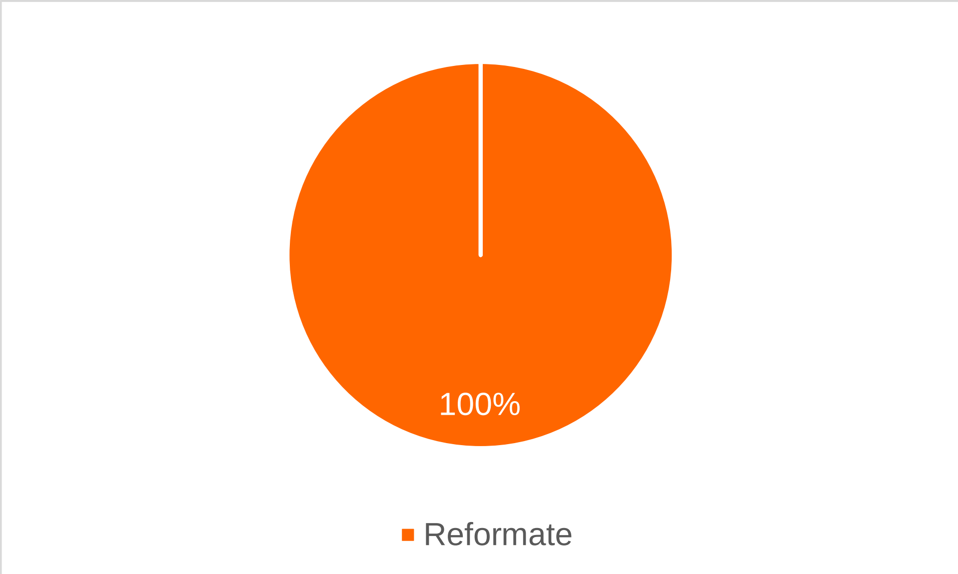
Figure 28: Consumption of gasoline in Bolivia



Source: ANH, 2021

Bolivia has a refining capacity of 3 to 10 million liters per day. The gasoline component used primarily is reformate.

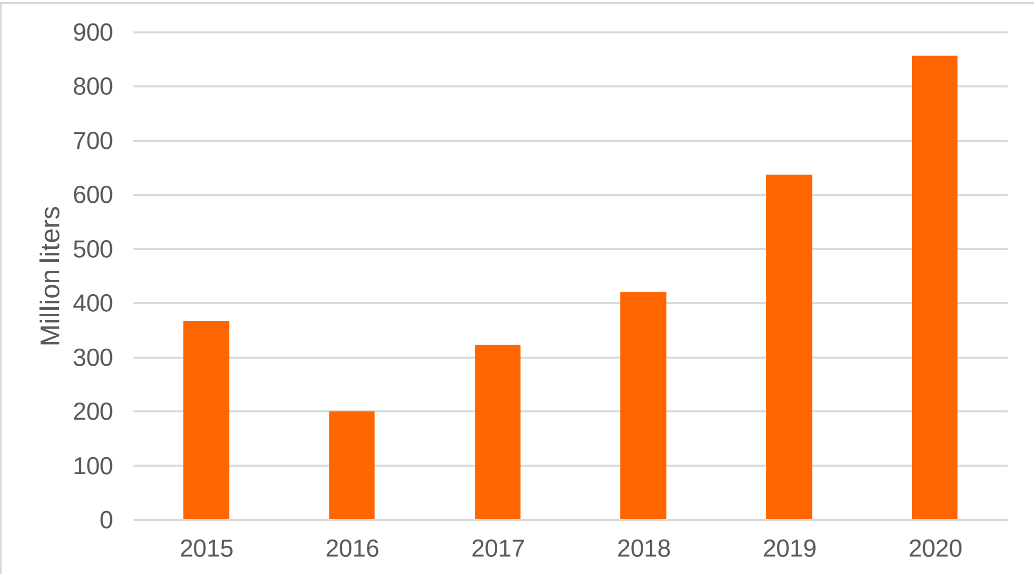
Figure 29: Gasoline blendstock mix in Bolivia



Source: HCX

Bolivia imports most of its fuel from Brazil, Chile, Argentina, and the United States.

Figure 30: Bolivia gasoline imports



Source: YPBF, 2021

Although gasoline E12 and E8 are being commercialized in Bolivia, there is no ethanol mandate. Several measures have been implemented to promote the production and commercialization of fuel ethanol.

In 2017, the government of Bolivia outlined the benefits of a national ethanol policy, which would bring economic growth, reduction of gasoline imports, potential blend of 15% with gasoline, and reduction of greenhouse gas (GHG) emissions.

In March 2018, the Minister of Hydrocarbons, YPFB - the state-owned oil and gas company and the Federation of entrepreneurs of Santa Cruz, signed a memorandum aiming to achieve the production of 80 million liters of ethanol in 2018.

On September 5, 2018, the Bolivian Chamber of Deputies voted for the project of law N° 303/2018-2019. The purpose of this law was to establish the regulatory framework allowing the production, storage, transportation, commercialization and mixing of biofuels, with the purpose of gradually replacing imports while protecting food safety and energy sovereignty. According to the law, the National Hydrocarbons Agency (in Spanish “Agencia Nacional de Hidrocarburos”, ANH) should be responsible for:

- Issuing operating licenses for the production, storage, transportation, and commercialization of biofuels
- Determining the proportion of biofuels to be blended with gasoline or diesel, in a percentage of up to 25%. This will be published through Supreme Decree
- Determining the technical specifications of the blended fuels

All the fuel ethanol consumed in Bolivia is produced in the country by 3 companies: Azúcar Aguaí, Ingenio Azucarero La Bélgica and Guabirá.

CARIBBEAN: DOMINICAN REPUBLIC

REGULATIONS

Gasoline

Gasoline specifications are depicted in NORDOM 476 and NORDOM 653, both with 1,500 mg/kg sulfur. Fuel quality specifications are implemented by the Ministry. There are two standards, one for gasoline and another for oxygenated gasoline. Octane for both grades are RON 89 and RON 96 respectively.

Ethanol

The Dominican Republic has standard NORDOM 653, from the Dominican Institute for Quality, issued in September 2010 for oxygenate blending with gasoline. Furthermore, Decree Number 566-05 established technical requirements for the import, production, storage, and distribution of ethanol blended with gasoline. This Decree gave a waiver of 1 psi (6.9 kPa) RVP to oxygenated gasoline. This Decree stipulates the necessary monitoring and control measurements against tank corrosion. Standard NORDOM 653 allows for maximum 10% v/v ethanol blended in gasoline, but no ethanol is blended into gasoline at the moment.

CURRENT FUEL QUALITY STANDARDS AND OBJECTIVES

Dominican Republic domestic gasoline specifications are Euro 0 enabling standards. The EU did not have specifications with 1,500 mg/kg; Euro specifications started with a stricter sulfur limit. Since benzene is not limited in the Dominican Republic, and benzene was regulated in the EU as of Euro 1, it can be concluded that specifications in the Dominican Republic are Euro 0.

Furthermore, there are no vehicle emissions standards in place.

COMPARISON AGAINST STANDARDS

Table below gives an overview of the comparison between the main properties in the Dominican Republic and in the EU. From the studied countries, the Dominican Republic is probably the country with the less similar specifications in relation to the EU.

Dominican Republic does not regulate hydrocarbons and implements a lower lead content limit than in the EU. The manganese content limit is also higher than in the EU. Octane, sulfur, and oxygen limits are less strict than in the EU as well.

Actual gasoline quality in Summer 2020 for the Dominican Republic complied with domestic specifications, but benzene, sulfur content and octane do not comply with EU specifications.

Actual quality in the next table is based on 8 samples (4 regular and 4 premium) collected in Santo Domingo in 2020.

Figure 31: Comparison between Dominican Republic and EU specifications

	Dominican Republic				DR actual gasoline Summer quality 2020 Average		EU			
Implementation Date	2010				N/A		2017			
Selected Grade	Regular gasoline for oxygenate blending	Premium gasoline for oxygenate blending	Regular oxygenated gasoline	Premium oxygenated gasoline	Regular unleaded 89	Premium unleaded 95	RON 95 E5	RON 95 E10	RON 98 E5	RON 98 E10
Name	NORDOM 653				Average values		EN 228:2012 + A1:2017 (Euro 6 enabling)			
Benzene Content	-				**1.34% v/v**		< 1 %v/v			
Aromatics	-				34.2% v/v		< 35 %v/v			
Olefins	-				15.2% v/v		< 18 %v/v			
Lead Content	< 0.013 g/l				< 0.0025 g/l		< 5 mg/l			
Manganese	< 8.3 mg/l (gasoline with no ethanol)				< 0.1 mg/l		< 2.0 mg/l			
RON	> 86	> 91	> 90	> 96	**92.7**	**95.3**	> 95	> 95	> 98	> 98
MON	> 73	> 78	> 77	> 83	**82.9**	**84.1**	> 85	> 88	> 85	> 88
Sulfur Content	< 1500 mg/kg				**39.5 mg/kg**		< 10 mg/kg			
Oxygen Content	< 3.5 %m/m (gasoline with ethanol)				-		< 2.7 %m/m	< 3.7 %m/m	< 2.7 %m/m	< 3.7 %m/m
Ethanol (EtOH)	< 10 %v/v				0% v/v		< 5 %v/v	< 10 %v/v	< 5 %v/v	< 10 %v/v
RVP 37.8°C (Summer)	< 61 kPa		< 69 kPa		52.7 kPa	52.1 kPa	<> 60 - 70 kPa *Depends on the country, RVP is regulated in the EU Fuel Quality Directive			
Ethers 5 or more C Atoms	-				0% v/v		Based on oxygen content	< 22 %v/v	Based on oxygen content	< 22 %v/v

*In orange the values that would not comply with EU specifications and in blue the values that do not comply with Dominican specifications.

Source: Dominican Republic and EU specifications, SGS Worldwide Fuel Survey, 2021

BLENDSTOCK ANALYSIS

The Dominican Republic has domestic gasoline production, which is complemented with imports. REFIDOMSA is the national oil company. In 2019, the refinery covered 20% of the gasoline domestic demand, according to the Economic Commission for Latin America and the Caribbean (CEPAL).

In Figure 32, fuel distribution companies supplying in the country, and the countries from which gasoline is imported, are shown.

Figure 32: Fuel companies and share of gasoline imports by origin, 2019

National large companies: Coastal, Costasur, Gulfstream, V Energy and Refidomsa.

National small companies: Interquímica, Laesa, Lear, Transcontinental.

Refidomsa and Coastal are the only two domestic companies. Refidomsa is the only company refining oil products.

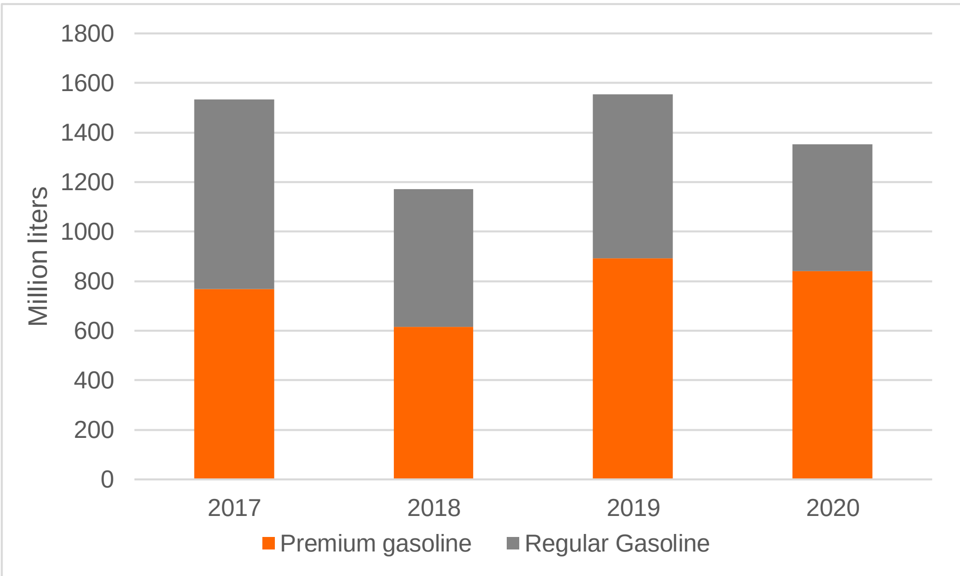
Source: CEPAL, based on official data of the Directorate of Fuels from the DR Ministry of Industry, Trade and SMEs, 2021

The gasoline component produced primarily in the Dominican Republic is reformate since the refining capacity is very simple. The Dominican Republic gasoline blendstock mix would include also catalytic gasoline as well, due to U.S. gasoline imports.

The Dominican Republic doesn´t have an ethanol mandate.

In 2019, the Dominican Republic consumed 892 million liters of gasoline premium and 663 million liters of gasoline regular, as indicated in the figure below.

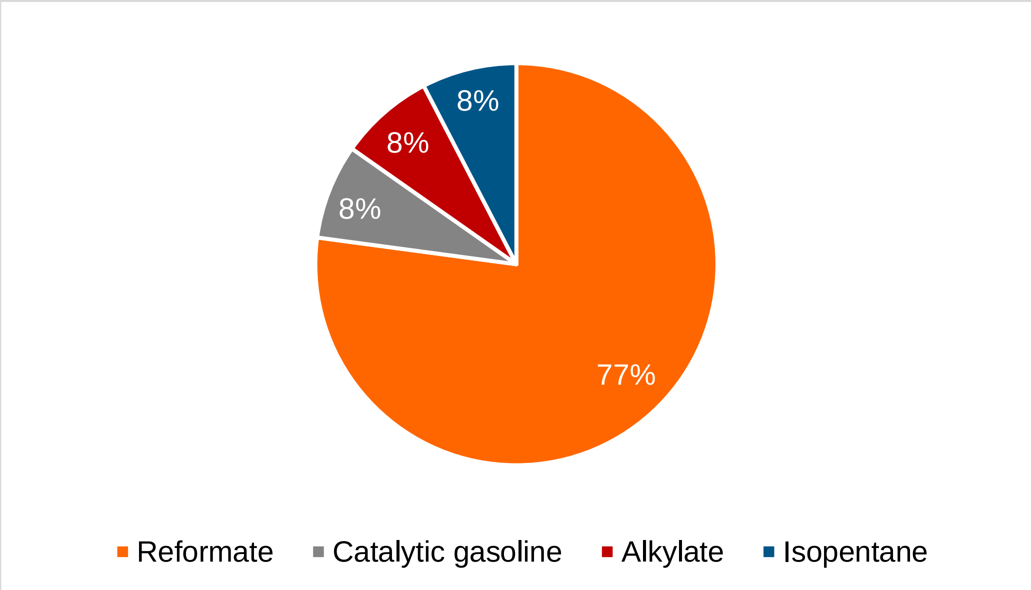
Figure 33: Gasoline consumption in the Dominican Republic



Source: Ministry of Trade, 2021

The Dominican Republic produces 20% of the gasoline the country consumes. Considering this, together with the origin of the imports, has brought SGS INSPIRE to estimate the blending components mix of the total gasoline demand.

Figure 34: Gasoline blending components produced in Dominican Republic



Source: Ministry of Trade, CEPAL, EIA, SGS INSPIRE Compilation

CARIBBEAN: JAMAICA

REGULATIONS

Gasoline

Gasoline specifications are depicted in standard JS 341:2017, with 1,500 mg/kg sulfur. Fuel quality specifications implemented by the Ministry but drafted by the Bureau of Standards of Jamaica. There are two standards, one for gasoline and another for oxygenated gasoline. Octane for both grades are AKI 87 and AKI 90 respectively.

Ethanol

Jamaica has standard JS 341:2017, which allows for E10 grade with AKI 87 and AKI 90, with ethanol content of between 9 and 10% v/v.

CURRENT FUEL QUALITY STANDARDS AND OBJECTIVES

Jamaica domestic gasoline specifications are Euro 1 enabling standards. The EU did not have specifications with 1,500 mg/kg; Euro specifications started with a stricter sulfur limit. Since benzene is limited in Jamaica, and benzene was regulated in the EU as of Euro 1, it can be concluded that specifications in Jamaica are Euro 1.

Furthermore, there are no vehicle emissions standards in place.

COMPARISON AGAINST STANDARDS

Table below gives an overview of the comparison between the main properties in the Jamaica and in the EU.

Octane is regulated as AKI in Jamaica, not as RON and MON like in the EU. Jamaica allows for a MTBE content of 15% v/v, being the only ether allowed. This is also different from EU specifications, with a max ether content of 22% v/v. In the next figure it is observed that actual quality complies with Jamaican specifications for all parameters except for RVP for the regular grade and the ethanol mandate, which is 0.57% v/v lower than the 10% v/v blend mandate. Octane complies with Jamaican specifications, but values are lower than EU minimum limits.

Actual quality in Figure 35 is based on 6 samples (3 regular and 3 premium) collected in Kingston and Ocho Ríos in 2020. It gives an overview of this comparison about the main properties in Jamaica.

Figure 35: Comparison between Jamaica and EU specifications

	Jamaica specifications		**Gasoline actual quality Summer 2020 Average**		**EU**			
Implementation Date	2017		Survey performed by SGS in limited number of stations across the country		2017			
Selected Grade	Unleaded petrol AKI 87 E10	Unleaded petrol AKI 90 E10	Regular E10	Premium E10	RON 95 E5	RON 95 E10	RON 98 E5	RON 98 E10
Name	JS 341:2017		Average values		EN 228:2012 + A1:2017 (Euro 6 enabling)			
Benzene Content	< 5 %v/v		1.07% v/v		< 1 %v/v			
Aromatics	< 45 %v/v		27.9% v/v		< 35 %v/v			
Olefins	-		6.8% v/v		< 18 %v/v			
Lead Content	< 0.013 g/l		< 0.0025 g/l		< 5 mg/l			

Manganese	< 18 mg/l		0 mg/l		< 2.0 mg/l			
RON			**93.6**	**96.6**	> 95	> 95	> 98	> 98
MON			**84.3**	**85.2**	> 85	> 88	> 85	> 88
AKI	90	87	90.9	89				
Sulfur Content	< 1500 mg/kg		18.5 mg/kg		< 10 mg/kg			
Oxygen Content	< 4 %m/m (gasoline with ethanol)		3.5% m/m		< 2.7 %m/m	< 3.7 %m/m	< 2.7 %m/m	< 3.7 %m/m
Ethanol (EtOH)	< 10 %v/v		**9.43% v/v**		< 5 %v/v	< 10 %v/v	< 5 %v/v	< 10 %v/v
RVP 37.8°C (Summer)	< 61 kPa	< 69 kPa	**65.6 kPa**	65.6 kPa	<> 60 - 70 kPa *Depends on the country, RVP is regulated in the EU Fuel Quality Directive			
MTBE	< 15% v/v for gasoline with no ethanol		0% v/v		-			
Ethers 5 or more C Atoms	15% v/v (other oxygenates)		0% v/v		Based on oxygen content	< 22 %v/v	Based on oxygen content	< 22 %v/v

*In orange the values that would not comply with EU specifications and in blue the values that do not comply with Jamaican specifications.

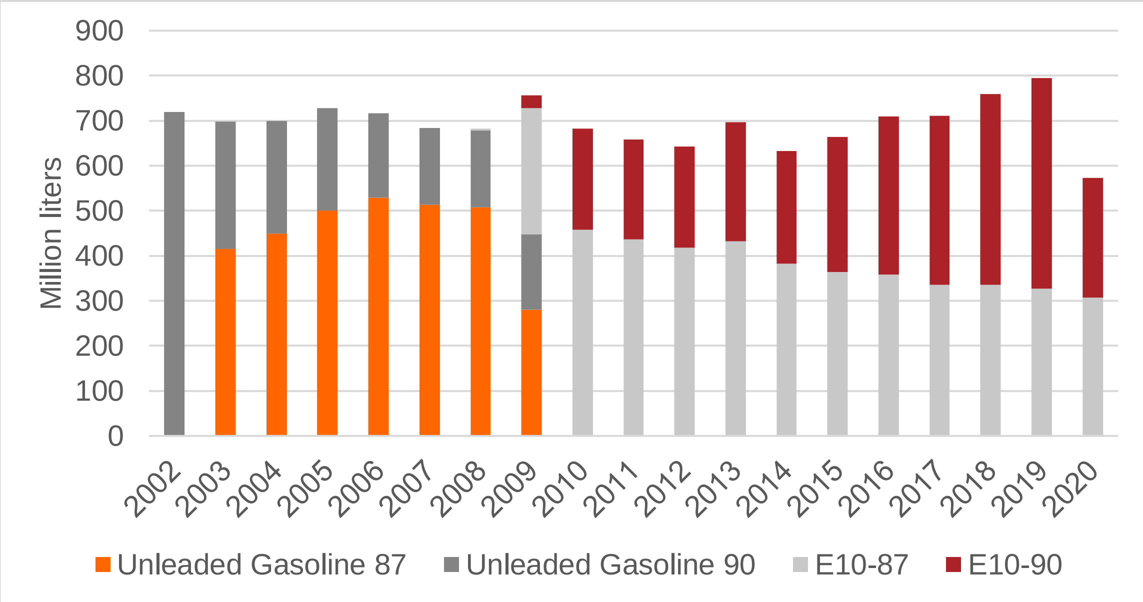
Source: Jamaican and EU specifications, SGS Worldwide Fuel Survey, 2021

BLENDSTOCK ANALYSIS

Jamaica has only consumed E10 gasoline since 2010. The shares of AKI 87 and AKI 90 are similar, with increasing growth of AKI 90 in recent years. Due to the COVID-19 pandemic, sales of AKI 90 decreased significantly in 2020. According to Petrojam, Jamaica produced 377 million liters AKI 90 gasoline in 2020.

Jamaica implemented an E10 gasoline mandate in 2010. It was fully implemented then as all gasoline supplied in the market as of 2010 contained ethanol. Furthermore, in 2018 the Government started planning to increase the ethanol mandate to 15% v/v, but nothing has been confirmed yet.

Figure 36: Ethanol blend consumption in Jamaica, 2002-2020

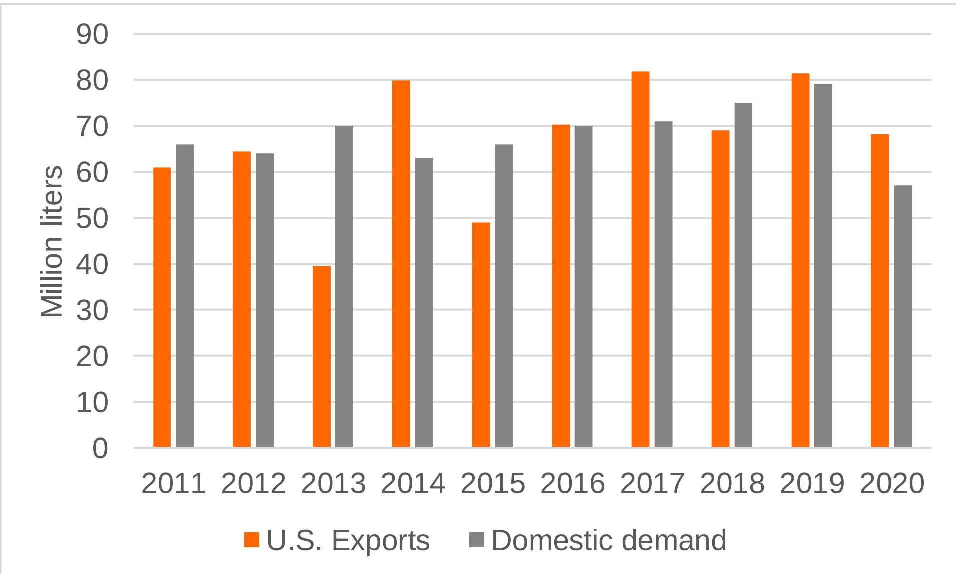


Source: Ministry of Energy of Jamaica

In Jamaica there are several ethanol producing companies, being the most important one Petrojam Ethanol Company Limited (PEL), owned by Petrojam. This company, however, has not been producing ethanol in the past years.

Considering domestic gasoline demand in Jamaica, total ethanol demand can be calculated, since the 10% v/v ethanol in gasoline blend mandate is being fulfilled, as SGS Worldwide Fuel Survey data shows. Figure 37 shows how Jamaica imports almost all its ethanol needs from the U.S.

Figure 37: Ethanol supply and demand in Jamaica



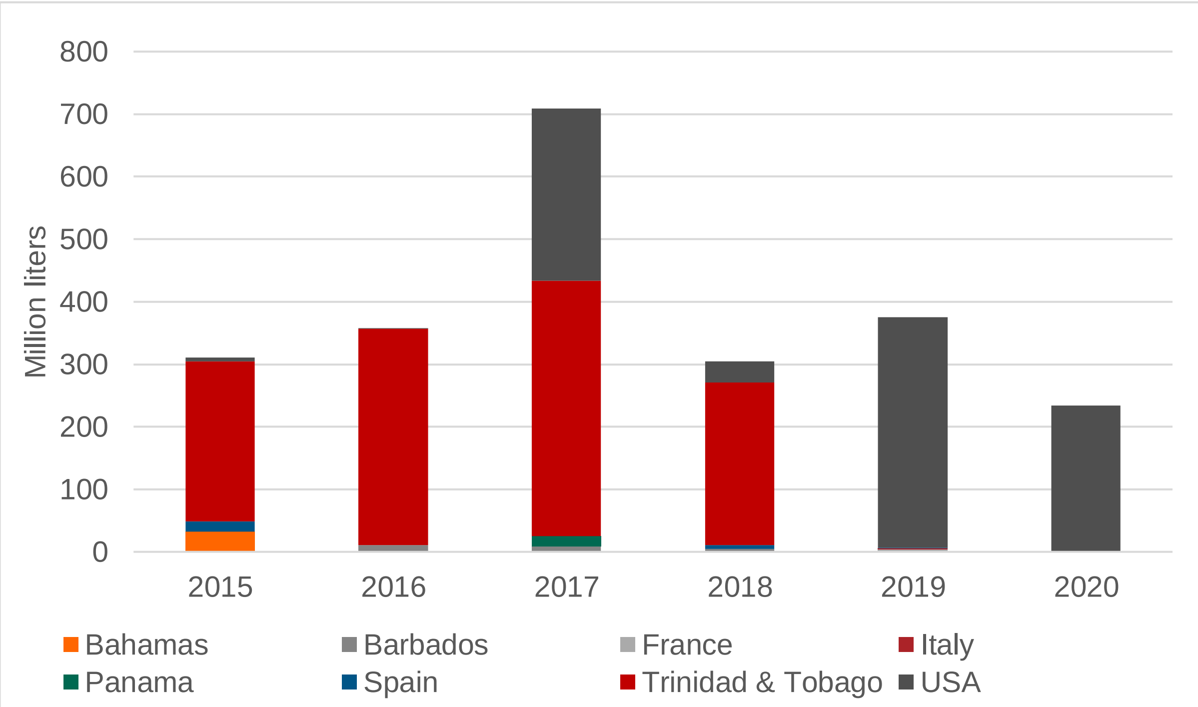
Source: EIA, Ministry of Petroleum of Jamaica

Jamaica started to have significant gasoline imports from the U.S. in 2019.

According to the United Nations Comtrade database, imports to Jamaica of HS commodity code 271012 Petroleum spirit for motor vehicles were almost 400 million liters in 2019, and most of them came from the U.S. According to the EIA, Jamaica imported 234 million liters of gasoline.

The origin of gasoline imports has significantly changed since Trinidad & Tobago ceased imports to Jamaica in 2019. This is due to its reduced capacity to produce fuels in the past years.

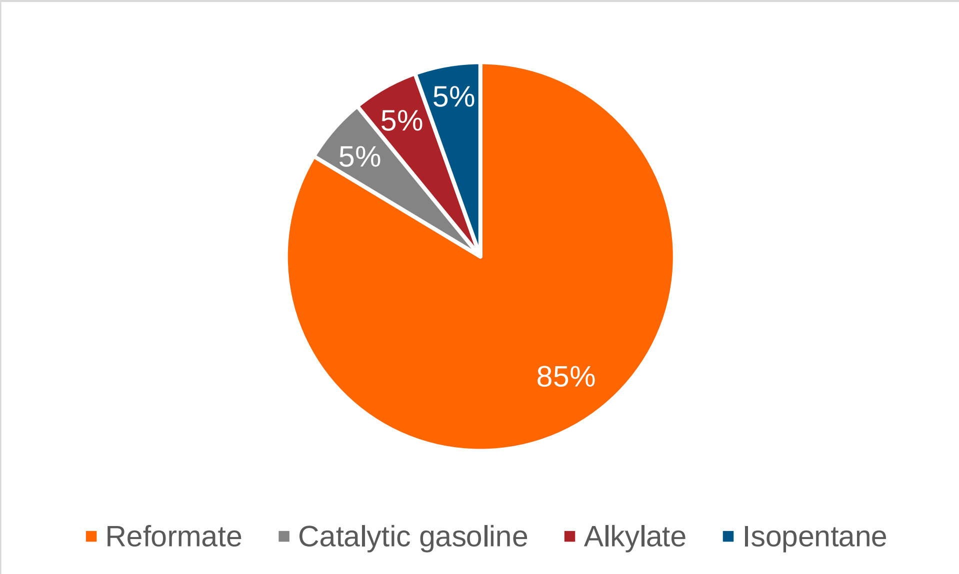
Figure 38: Jamaica gasoline imports per year and country



Source: UN Comtrade, 2021

Therefore, it can be concluded that Jamaica produced domestically 281 million liters and imported 234 million liters of gasoline. The gasoline component produced primarily in Jamaica is reformate since the refining capacity is very simple, but the blending components mix is richer because of the blendstocks used in U.S. gasoline. An average of blending components in Jamaica can be seen in the figure below.

Figure 39: Gasoline blending components produced in Jamaica



Source: Ministry of Energy, UN Comtrade, EIA, SGS INSPIRE Compilation

CENTRAL AMERICA

REGULATIONS

Gasoline

Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama are members of the Secretariat of Central American Economic Integration (SIECA), an institution that acts as the technical and administrative body of the Central American Ministers Council for Economic Integration (COMIECO).

Through different resolutions, the COMIECO has approved Central American Technical Regulations (Reglamentos Técnicos Centroamericanos, RTCA) that define fuel specifications. For gasoline, the latest two resolutions that approved the RTCA specifications are:

- Resolution 425-2020: approved RTCA 75.01.20:19, defining specifications of gasoline premium (in Spanish: “Gasolina Superior”). It sets a minimum RON of 95, and a maximum sulfur content of 50 mg/kg in Costa Rica, 150 mg/kg in Panama and 500 mg/kg in Guatemala, El Salvador, Honduras, and Nicaragua
- Resolution 425-2020: approved RTCA 75.01.19:19, defining specifications of gasoline regular (in Spanish: “Gasolina Regular”). It sets a minimum RON of 91 except for Nicaragua and Guatemala (RON 88), and a maximum sulfur content of 50 mg/kg in Costa Rica, 150 mg/kg in Panama and 500 mg/kg in Guatemala, El Salvador, and Honduras

After their publication, RTCA specifications must be implemented and published in the national legislation of the COMIECO member countries. Resolution 425-2020 entered into force on February 1, 2021, in Costa Rica, Guatemala, Honduras, El Salvador, Panama and on June 23, 2021, in Nicaragua and it should be published by each Member State.

The regulatory limits for RON and sulfur content of the two grades of gasoline in the Central American countries are compared in Figure 40.

Figure 40: Gasoline grades in Central America

	Gasoline Regular, Min RON	Gasoline Premium, Min RON	Max Sulfur Content (mg/kg)
Costa Rica	91	95	50
El Salvador	91	95	500
Guatemala	88	95	500
Honduras	91	95	500
Nicaragua	88	95	500
Panama	91	95	150

Source: National and regional gasoline specifications

Ethanol

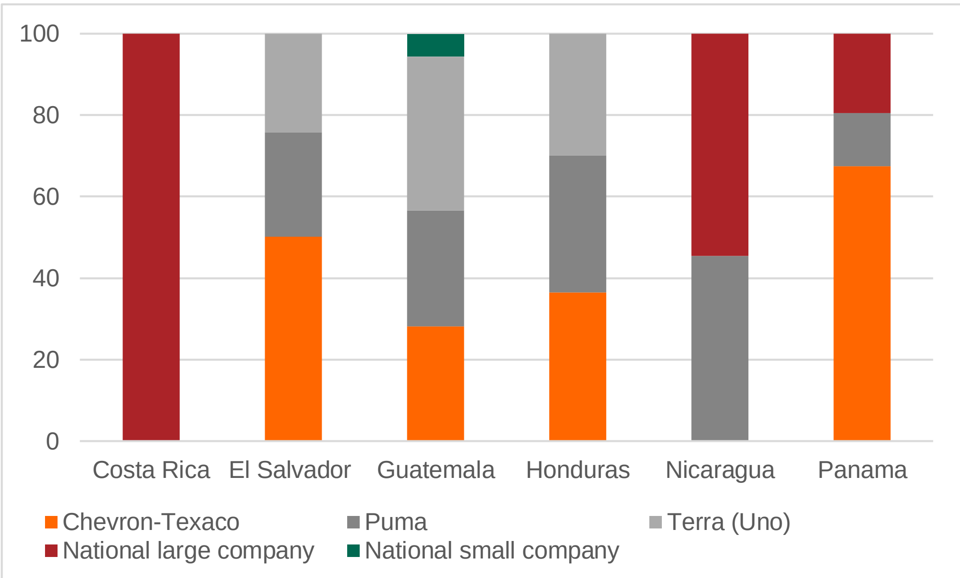
Regional standard RTCA 75.02.46:07 defines specifications of anhydrous ethanol. It states that gasoline blended with ethanol in a proportion up to 10% v/v must comply with RTCA specifications for gasoline regular and premium. Gasoline blended with more than 10% v/v ethanol must comply with specifications established by the competent national entity of each member state.

BLENDSTOCK ANALYSIS

Since gasoline production only takes place in Nicaragua, and gasoline imports come to the region from the U.S. and to a lesser extent from Europe, SGS INSPIRE has analyzed the fuel distribution information to understand better gasoline blendstocks used in Central America.

The share of gasoline and diesel imported by company (origin and size) and by country is analyzed below. The two international companies supplying gasoline in Central America are Chevron-Texaco and Esso (Exxon). Puma and Terra, under the Uno brand, are the two regional companies distributing gasoline. Other companies supplying fuels are national, both large and small companies. As observed, Nicaragua does not distribute fuels from any international company directly, since they have domestic production. Costa Rica has a national oil company, RECOPE, that does not refine but distributes 100% of the fuels. Regional companies are present in every country except for Costa Rica, and only Guatemala has small national companies distributing fuels.

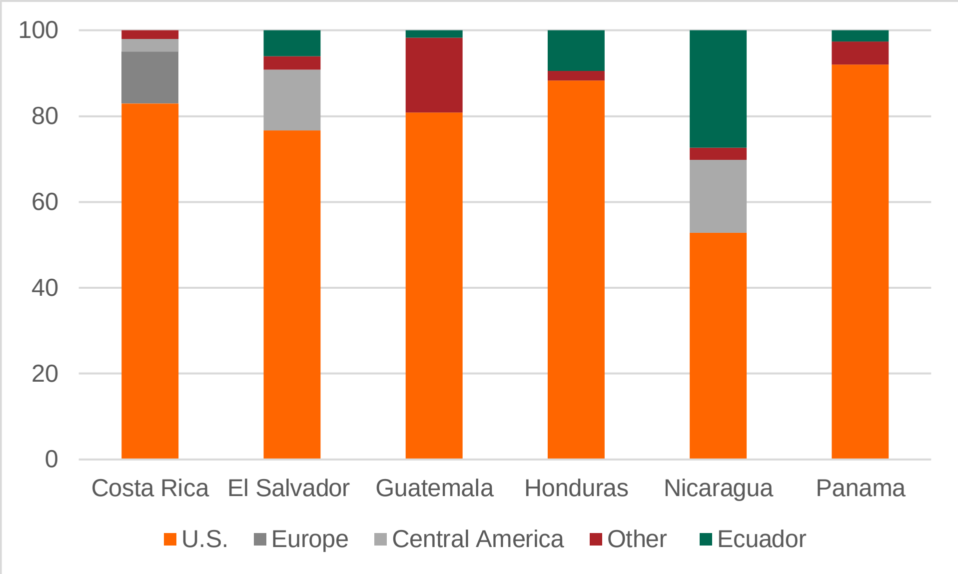
Figure 41: Share (%) of gasoline and diesel imported and refined by company and country, Central America, 2019



Source: CEPAL, 2021

Even though companies distributing fuels differ per country, most fuels are imported from the U.S., with small variations amongst the countries.

Figure 42: Gasoline imports by country of origin in Central America, 2019

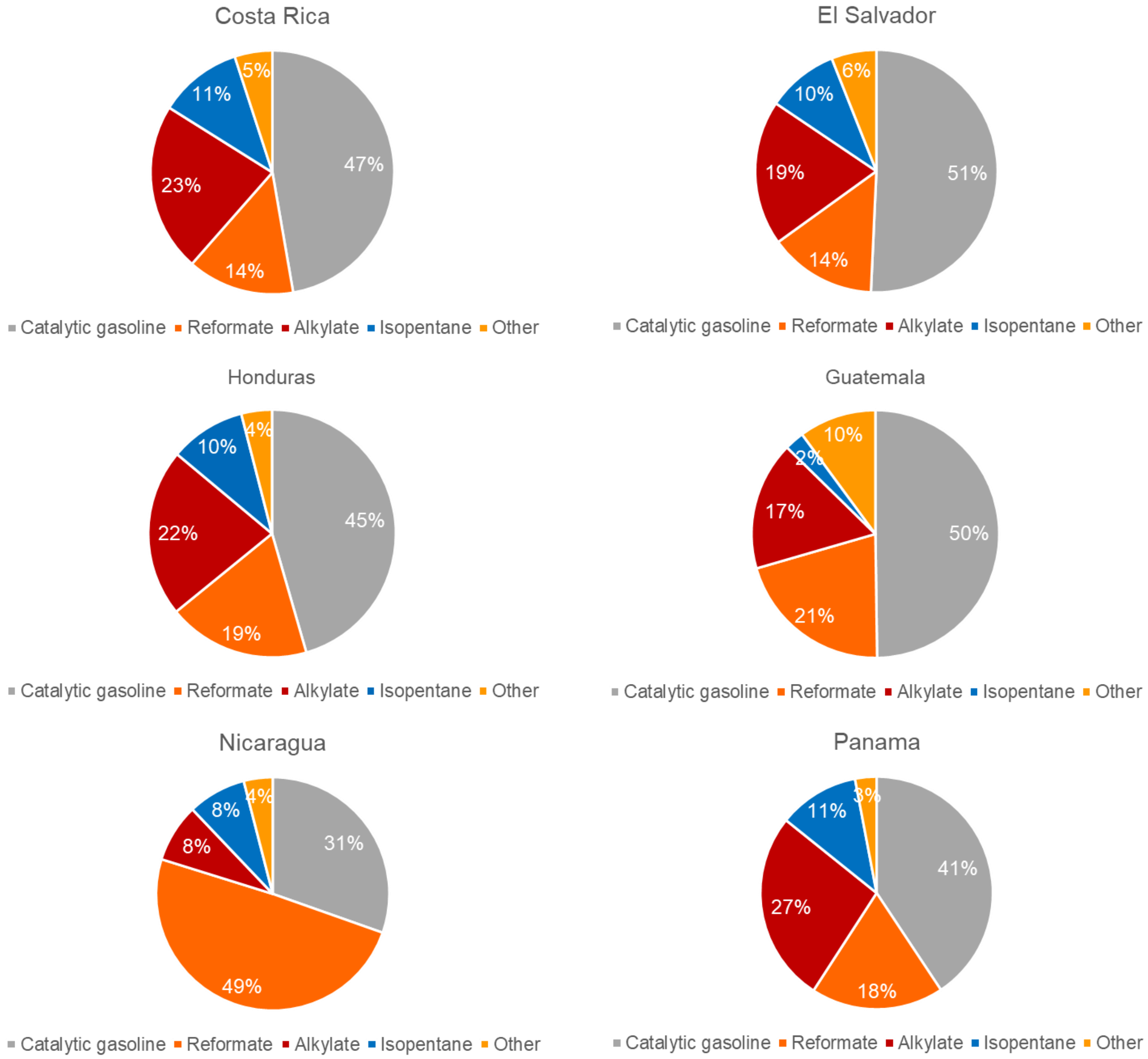


Source: CEPAL, 2021

These data can be extrapolated to an average gasoline blendstock mix used in each country, considering as mentioned earlier in the report, that the blendstock mix differ from batch to batch. The mix of blending components has been calculated on the basis of the gasoline blendstock mix of countries of imports' origin (U.S., Europe, Ecuador, Central America and other) and domestic production for Nicaragua. Also, the share of premium and regular gasoline has been taken into account, since the gasoline blending components used to produce the two grades in the U.S. differ.

As can be seen in Figure 43, blending components used are mostly catalytic gasoline, reformate, alkylate and isopentane. Shares per blending component differ per country depending on the country of origin of imports and company supplying, and whether the country counts with domestic refining industry.

Figure 43: Gasoline blending components in Central America per country



Source: Regional and national sources, SGS INSPIRE Compilation

CENTRAL AMERICA: COSTA RICA

REGULATIONS

Gasoline

In Costa Rica, the Institute of Technical Standards of Costa Rica (Instituto de Normas Técnicas de Costa Rica (INTECO)) published in 2020 the national standard for gasoline INTE E1:2019, which details the specifications for gasoline RON 91, RON 95, and the blends of gasoline with denatured anhydrous ethanol called EX – where X is the percentage of ethanol. This national standard is applicable since 2020.

Ethanol

In Costa Rica, the national standard INTE E5:2017 defines the specifications of anhydrous ethanol.

CURRENT FUEL QUALITY STANDARDS AND OBJECTIVES

Costa Rica has gasoline and ethanol blend specifications; these are equivalent to Euro 4 enabling gasoline standards. Not all properties are the same as European specifications, this comparison is mostly based on sulfur limit.

Furthermore, emissions standards for imported vehicles were Euro 4 since January 1, 2018 and Euro 6 since January 1, 2021.

COMPARISON AGAINST STANDARDS

Figure 44 presents the comparison of the main properties in Costa Rica and the EU. It can be seen that Costa Rican specifications follow EU standards. However, benzene, sulfur and RVP limits are higher, and RON and MON are lower than in EU specifications.

The actual quality is more similar to EU specifications than Central American specifications, which means that gasoline has improved in the past years.

Actual quality shown is the average values of 8 samples: 4 samples of regular RON 91 and 4 samples of premium RON 95 collected in Rita, Cartago, San José and Grecia.

Figure 44: Comparison between Costa Rica and EU specifications and actual quality data

	Costa Rica Specifications		**Costa Rica actual gasoline quality Winter 2019/2020 SGS WWFS Average**		**EU Specifications**			
Implementation Date	2019		-		2017			
Selected Grade	RON 91	RON 95	Regular 91	Premium 95	RON 95 E5	RON 95 E10	RON 98 E5	RON 98 E10
Name	INTE E1:2019		Average values		EN 228:2012 + A1:2017 (Euro 6 enabling)			
Benzene Content	< 1.5% v/v		0.56% v/v		< 1 %v/v			
Aromatics	< 35% v/v		21.3% v/v		< 35 %v/v			
Olefins	< 18% v/v		10.8% v/v		< 18 %v/v			
Lead Content	< 0.013 g/l		< 2.5 mg/l		< 5 mg/l			
Manganese	< 2.0 mg/l		< 0.1 mg/l		< 2.0 mg/l			
RON	> 91	> 95	**92.2**	**95.5**	> 95	> 95	> 98	> 98
MON	> 79	> 83	**83.8**	**85.9**	> 85	> 88	> 85	> 88
Sulfur Content	< 50 mg/kg		**18.9**		< 10 mg/kg			

Oxygen Content	2.7% m/m (3.7% m/m if ethanol is added)	-	< 2.7 %m/m	< 3.7 %m/m	< 2.7 %m/m	< 3.7 %m/m
Ethanol (EtOH)	< 10% v/v	0% v/v	< 5 %v/v	< 10 %v/v	< 5 %v/v	< 10 %v/v
RVP 37.8°C (Summer)	< 69 kPa (< 76 kPa if ethanol is added)	62.4 kPa	<> 60 - 70 kPa *Depends on the country, RVP is regulated in the EU Fuel Quality Directive			
MTBE	-	0.50% v/v	-			
Ethers 5 or more C Atoms	-	0.50% v/v	Based on oxygen content	< 22 %v/v	Based on oxygen content	< 22 %v/v

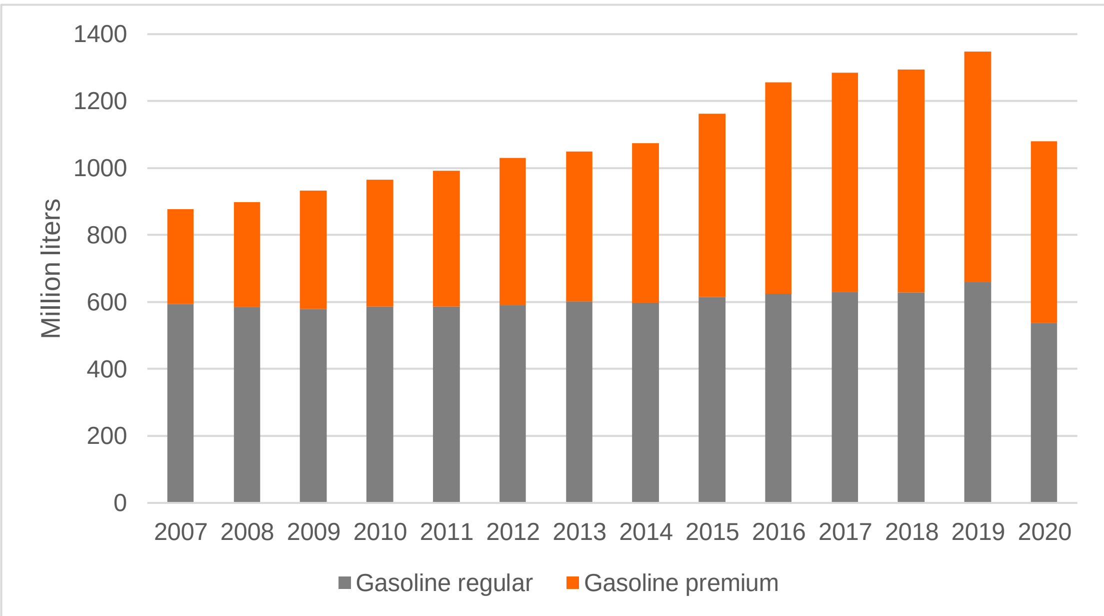
*In orange the values that would not comply with EU specifications and in blue the values that do not comply with Costa Rican specifications.

Source: Costa Rica and EU specifications, SGS Worldwide Fuel Survey, 2021

BLENDSTOCK ANALYSIS

The consumption volumes of gasoline in Costa Rica are shown in Figure 45. In 2020 half of the gasoline consumption is regular and half is premium.

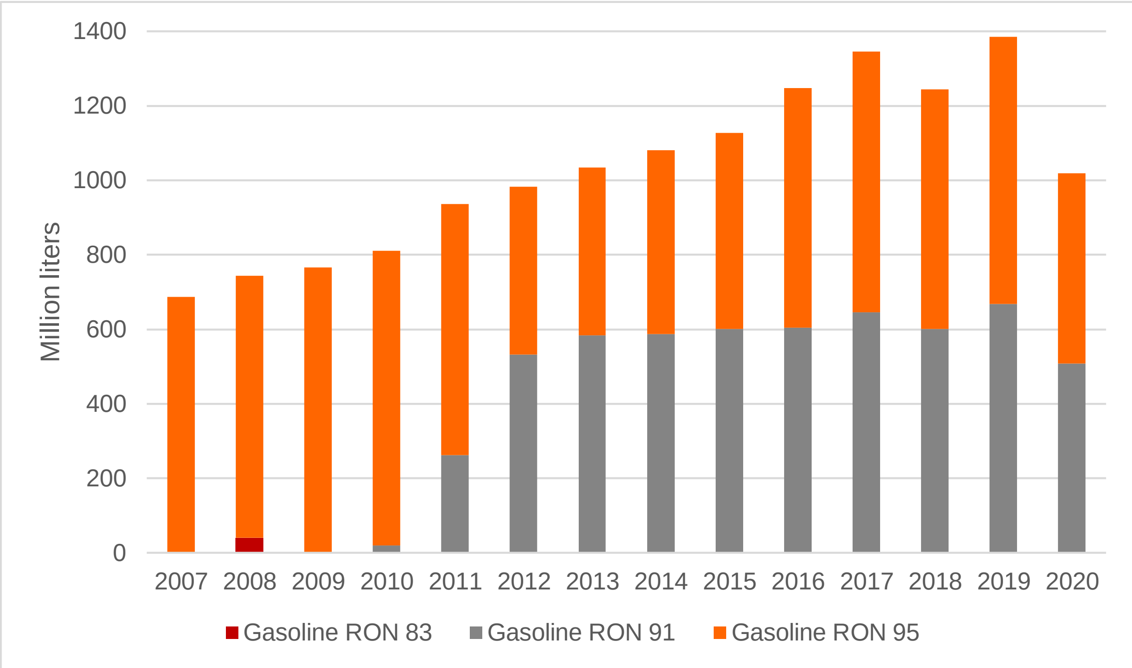
Figure 45: Consumption of gasoline in Costa Rica



Source: RECOPE, 2021

Costa Rica imports most of its fuel from the U.S. Further details are shown below.

Figure 46: Imports of gasoline in Costa Rica

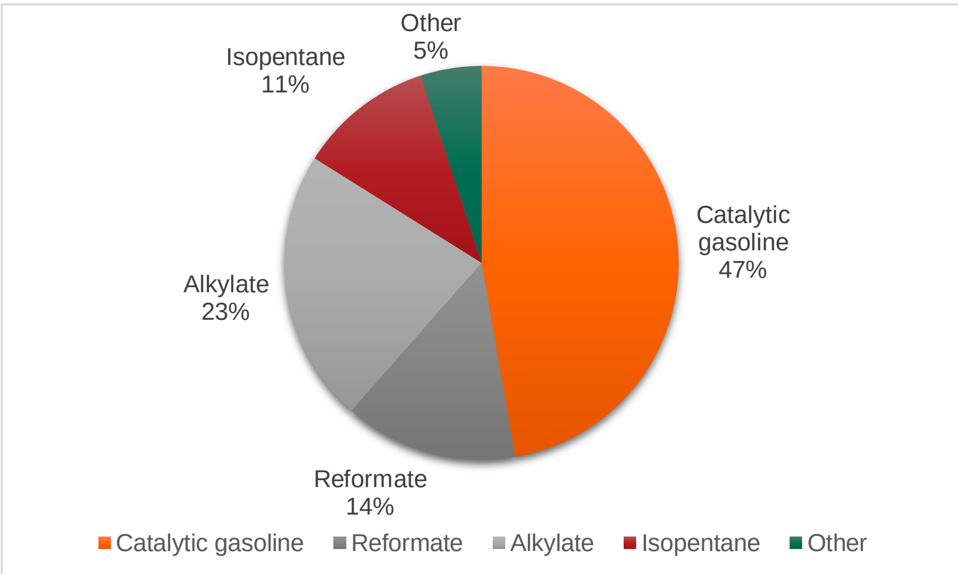


Source: RECOPE, 2021

From the Central American countries, only Nicaragua and Costa Rica have refining capacity, however Costa Rica is not producing any fuels at present.

Costa Rica's gasoline blending component mix is based mostly on U.S. imports and to a lesser extent, European imports.

Figure 47: Gasoline blending components produced in Costa Rica



Source: SGS INSPIRE Compilation

CENTRAL AMERICA: GUATEMALA

REGULATIONS

Gasoline

In Guatemala, the national standard NGO 51 015, published in the Official Journal on October 30, 1987, sets specifications for gasoline blended with 10% v/v ethanol (±0.5% volume). This was a grade of leaded gasoline with a RON of 91 and a maximum sulfur content of 1,500 mg/kg. The national standard NGO 51 015 has been superseded by the regional standards RTCA for gasoline.

Ethanol

No domestic specifications are available in Guatemala, only RTCA standards.

CURRENT FUEL QUALITY STANDARDS AND OBJECTIVES

Guatemala has Euro 2 enabling gasoline standards. Not all properties are the same as European specifications, this comparison is based on sulfur limits.

Furthermore, there are no vehicle emissions standards in place.

COMPARISON AGAINST STANDARDS

Table below presents the comparison of the main properties in Guatemala and the EU. Aromatics and olefins are regulated in Guatemala only since 2021. Limits for hydrocarbons, lead, octane, and sulfur are higher in Guatemala than in the EU.

The actual quality is more similar to EU specifications than Central American specifications, which means that gasoline has been improving in the past years. Values for all parameters comply with Guatemalan specifications, but sulfur and octane are out of the scope of the EU specifications.

Actual quality in the next table is based on 8 samples (4 regular and 4 premium) collected in Guatemala City.

Figure 48: Comparison between Guatemala and EU specifications

	Guatemala Specifications		**Guatemala actual gasoline Summer quality 2020 Average**		**EU Specifications**			
Implementation Date	2019/2021		N/A		2017			
Selected Grade	Gasoline Regular	Gasoline Superior	Gasoline Low Regular	Gasoline Superior	RON 95 E5	RON 95 E10	RON 98 E5	RON 98 E10
Name	Decree No. 364-2019 /Resolution 425/2020		Average values		EN 228:2012 + A1:2017 (Euro 6 enabling)			
Benzene Content	< 2.5 % v/v		0.92% v/v		< 1 %v/v			
Aromatics	- / < 50% v/v		28.9% v/v		< 35 %v/v			
Olefins	- / < 30% v/v		12.8% v/v		< 18 %v/v			
Lead Content	< 0.013 g/l				< 5 mg/l			
Manganese	< 2.5 mg/l				< 2.0 mg/l			
RON	> 88/ > 91* in 2022	> 95	90.3	95.3	> 95	> 95	> 98	> 98
MON	-		82.0	85.4	> 85	> 88	> 85	> 88
Sulfur Content	< 500 mg/kg		18 mg/kg		< 10 mg/kg			
Oxygen Content	-		-		< 2.7 %m/m	< 3.7 %m/m	< 2.7 %m/m	< 3.7 %m/m

Ethanol (EtOH)	< 10 %v/v	0% v/v	< 5 %v/v	< 10 %v/v	< 5 %v/v	< 10 %v/v
RVP 37.8°C (Summer)	< 69 kPa	60.1 kPa	<> 60 - 70 kPa *Depends on the country, RVP is regulated in the EU Fuel Quality Directive			
MTBE	10% v/v	0% v/v	-			
Ethers 5 or more C Atoms	-	0% v/v	Based on oxygen content	< 22 %v/v	Based on oxygen content	< 22 %v/v

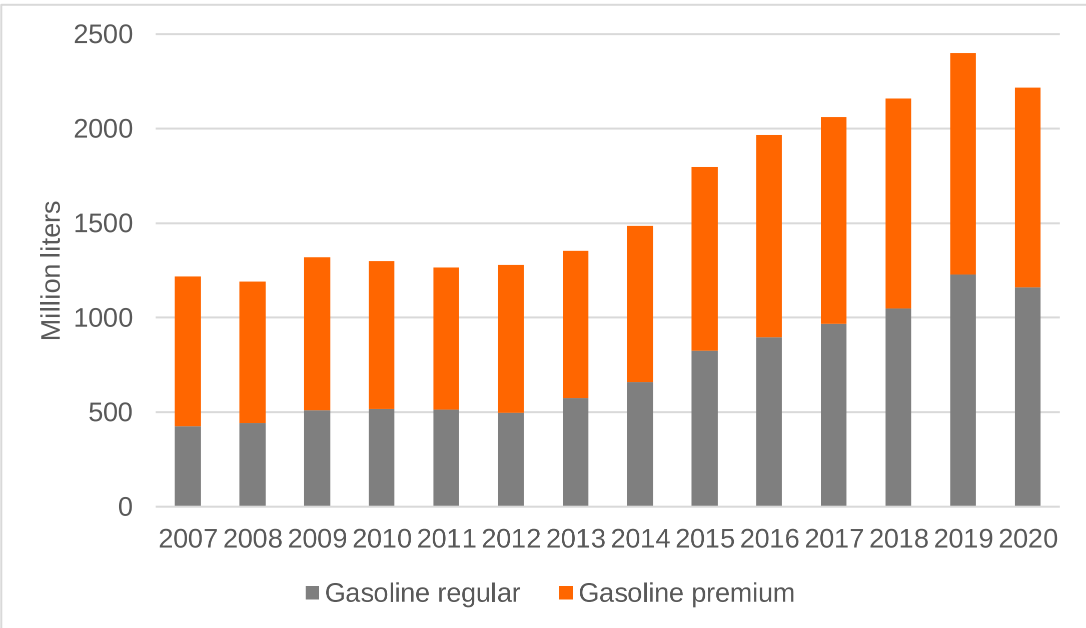
*In orange the values that would not comply with EU specifications and in blue the values that do not comply with Costa Rican specifications.

Source: Guatemalan and EU specifications, SGS Worldwide Fuel Survey, 2021

BLENDSTOCK ANALYSIS

The consumption volumes of gasoline in Guatemala are shown in figure below.

Figure 49: Consumption of gasoline in Guatemala

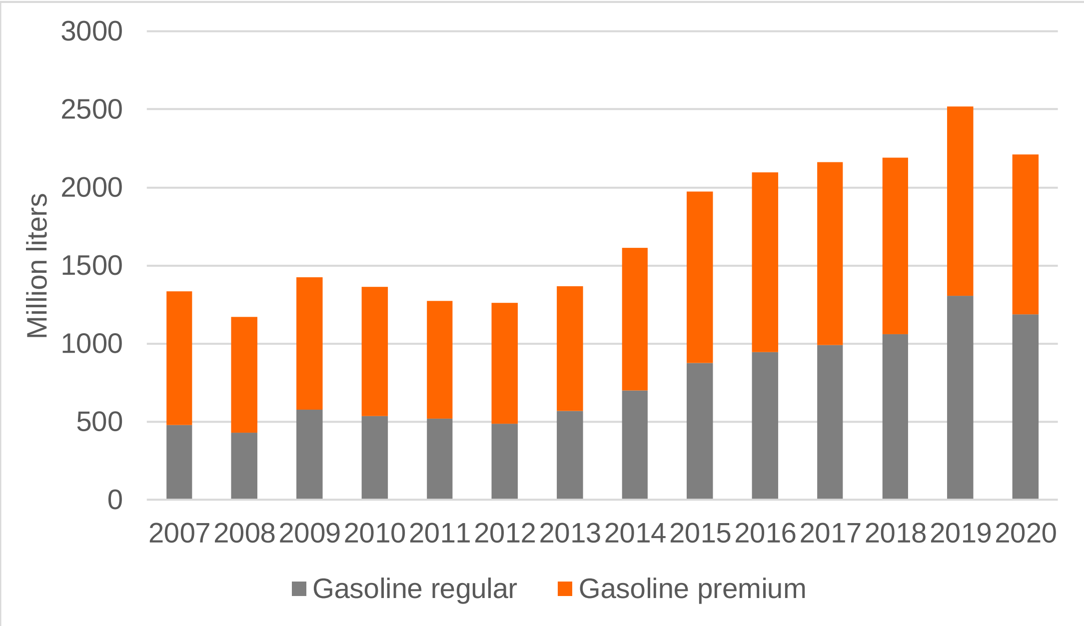


Source: Ministry of Energy and Mines, 2021

The volumes of imported and exported gasoline in Guatemala are shown in figure below.

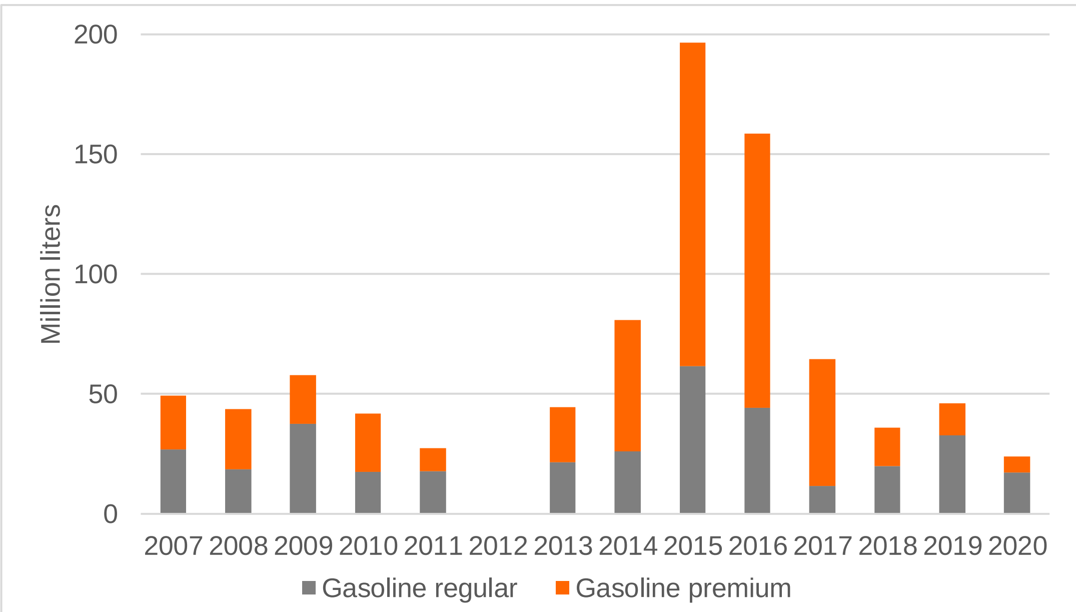
SGS SOL data indicate that almost 2,700 million liters of gasoline were imported by different terminals. Based on this data most gasoline was of an unspecified grade and gasoline RON 95 accounted for 400 million liters.

Figure 50: Imports of gasoline in Guatemala



Source: Ministry of Energy and Mines, 2021

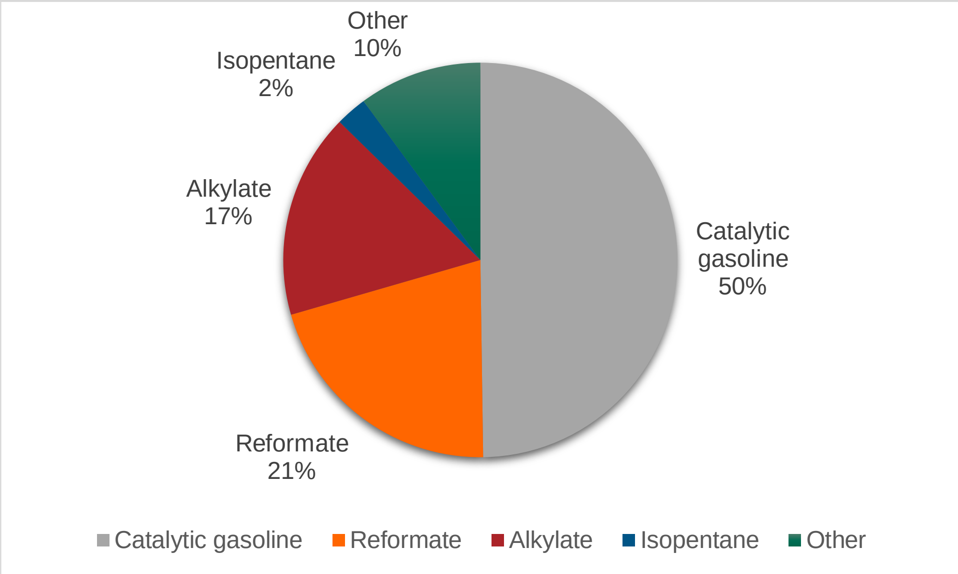
Figure 51: Exports of gasoline from Guatemala



Source: Ministry of Energy and Mines, 2021

Guatemala's gasoline blending component mix is based mostly on U.S. imports and, to a lesser extent, non-identified countries' imports.

Figure 52: Gasoline blending components produced in Guatemala



Source: SGS INSPIRE Compilation

CENTRAL AMERICA: EL SALVADOR

REGULATIONS

Gasoline

El Salvador defines gasoline specifications in RTCA standards (RTCA 75.01.20:19 for gasoline premium and RTCA 75.01.19:19 for gasoline regular).

Ethanol

No domestic specifications are available in El Salvador, only RTCA standards.

CURRENT FUEL QUALITY STANDARDS AND OBJECTIVES

El Salvador has Euro 2 enabling gasoline standards. Not all properties are the same as European specifications, this comparison is mostly done according to sulfur.

Furthermore, there are vehicle emissions standards in place, but these are pre Euro standards. Vehicle exhaust emission limits are set in the standard NSO 13.11.03:01, published in the Official Journal No. 360 on June 4, 2003. The regulated pollutants are hydrocarbons (HC), carbon dioxide (CO_2) and carbon monoxide (CO) and for spark-ignition vehicles.

COMPARISON AGAINST STANDARDS

Figure 53 gives an overview of this comparison about the main properties in El Salvador and the EU. The actual quality is more similar to EU specifications than Central American specifications, which means that gasoline has been improving in the past years. Limits for hydrocarbons, lead, octane, sulfur, and oxygen are less strict in El Salvador than in the EU.

As can be seen below, actual quality of gasoline in El Salvador meets Salvadorian and EU specifications, except for octane, which lower than what the regulation requires.

Actual quality shown in the table is the average values of 8 samples: 4 samples of regular RON 88 and 4 samples of premium RON 95 collected in Santa Ana and San Salvador.

Figure 53: Comparison between El Salvador and EU specifications and actual quality data

	El Salvador		**El Salvador actual gasoline quality Winter 2019/2020 SGS WWFS Average**		**EU**			
Implementation Date	2021	2021	-		2017			
Selected Grade	Gasoline Regular	Gasoline Premium	Regular	Premium	RON 95 E5	RON 95 E10	RON 98 E5	RON 98 E10
Name	RTCA 75.01.19:19	RTCA 75.01.20:19	Average values		EN 228:2012 + A1:2017 (Euro 6 enabling)			
Benzene Content	5% v/v		0.8 %v/v		< 1 %v/v			
Aromatics	50% v/v		29.2 %v/v		< 35 %v/v			
Olefins	30% v/v		14.2 %v/v		< 18 %v/v			
Lead Content	< 0.013 g/l		0.005 g/l		< 5 mg/l			
Manganese	2.0% v/v		< 0.1 mg/l		< 2.0 mg/l			
RON	> 91	> 95	**90.0**	**94.7**	> 95	> 95	> 98	> 98
MON	-		**81.8**	**85.1**	> 85	> 88	> 85	> 88

Sulfur Content	< 500 mg/kg	16 mg/kg	< 10 mg/kg			
Oxygen Content	0.7% v/v	-	< 2.7 %m/m	< 3.7 %m/m	< 2.7 %m/m	< 3.7 %m/m
Ethanol (EtOH)	-	0 %v/v	< 5 %v/v	< 10 %v/v	< 5 %v/v	< 10 %v/v
RVP 37.8°C (Summer)	< 69 kPa	62.7 kPa	<> 60 - 70 kPa *Depends on the country, RVP is regulated in the EU Fuel Quality Directive			
MTBE	-	0 %v/v	-			
Ethers 5 or more C Atoms	-	0 %v/v	Based on oxygen content	< 22 %v/v	Based on oxygen content	< 22 %v/v

*In orange the values that would not comply with EU specifications and in blue the values that do not comply with Salvadorian specifications.

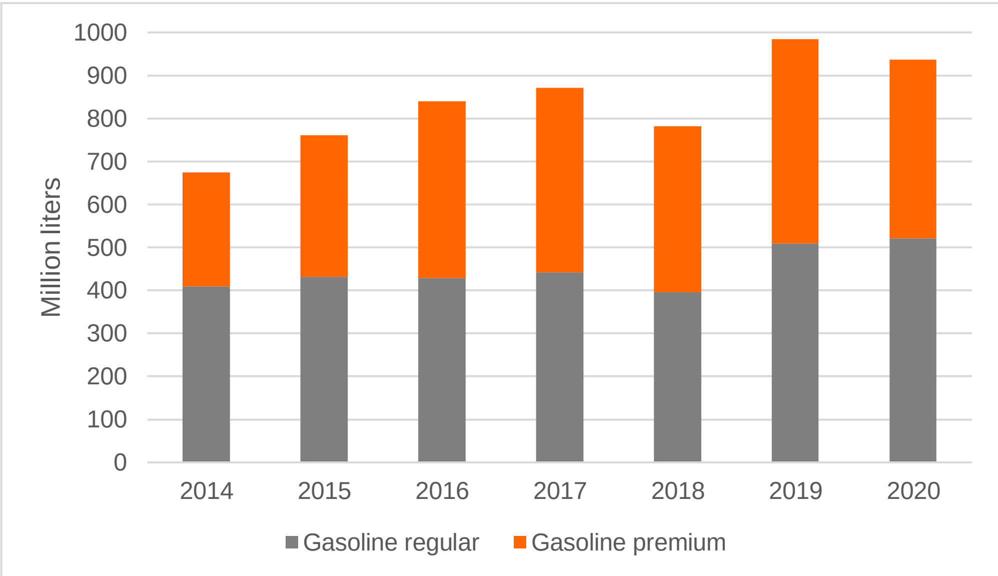
Source: El Salvador and EU specifications, SGS Worldwide Fuel Survey, 2021

BLENDSTOCK ANALYSIS

The consumption volumes of gasoline in El Salvador are shown in Figure 52. In 2020, gasoline regular amounted to 57% of the volume consumed, and gasoline premium to 43%.

Chevron distributes approximately 70% of the gasoline, Puma distributes 27% and Uno 3% as of April 2021.

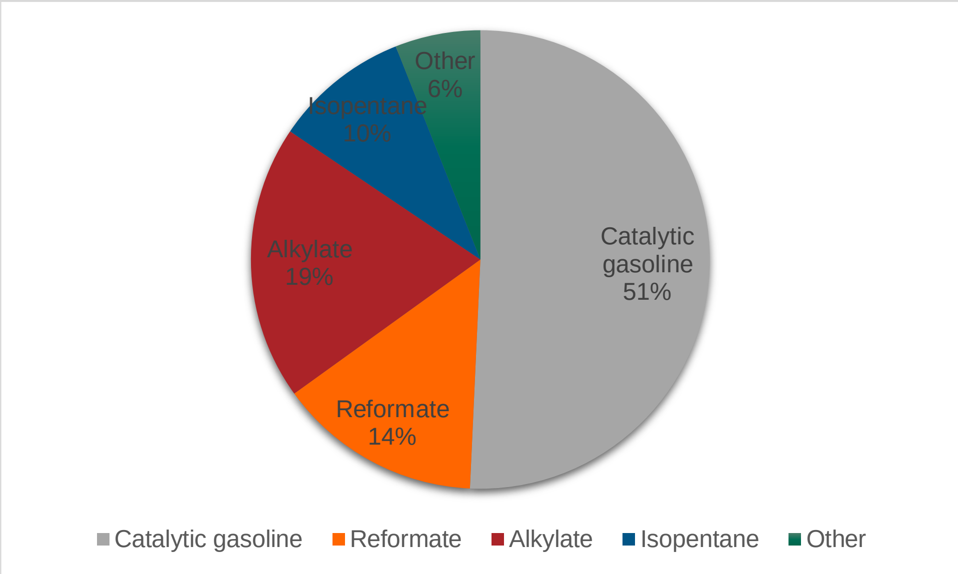
Figure 54: Consumption of gasoline in El Salvador



Source: Ministry of Economy, Directorate of Hydrocarbons and Mines, 2021

El Salvador's gasoline blending component mix is based mostly on U.S. imports and to a lesser extent, Ecuador, and other Central American countries' imports.

Figure 55: Gasoline blending components produced in El Salvador



Source: SGS INSPIRE Compilation

CENTRAL AMERICA: HONDURAS

REGULATIONS

Gasoline

Honduras defines gasoline specifications with RTCA standards (RTCA 75.01.20:19 for gasoline premium and RTCA 75.01.19:19 for gasoline regular).

Ethanol

No domestic specifications are available in Honduras, only RTCA standards.

CURRENT FUEL QUALITY STANDARDS AND OBJECTIVES

Honduras has Euro 2 enabling gasoline standards. Not all properties are the same as European specifications, this comparison is mostly done according to sulfur.

Furthermore, there are no vehicle emissions standards in place.

COMPARISON AGAINST STANDARDS

Figure 56 gives an overview of this comparison about the main properties in Honduras and the EU. The actual quality is more similar to EU specifications than Central American specifications, which means that gasoline has been improving in the past years.

Limits for hydrocarbons, lead, octane, sulfur, and oxygen are less strict in Honduras than in the EU.

As can be seen below, actual quality of gasoline in Honduras meets Honduran and EU specifications, except for octane, which are lower than what the regulation requires and sulfur, which is higher than what is required in the EU.

Actual quality shown in the table is the average values of 7 samples: 3 samples of regular RON 88 and 4 samples of premium RON 95 collected in San Pedro Sula.

Figure 56: Comparison between Honduras specifications and EU specifications and actual quality data

	Honduras		**Honduras actual gasoline winter 2019/2020 SGS WWFS Average**		**EU**			
Implementation Date	2021	2021	-		2017			
Selected Grade	Gasoline Premium	Gasoline Regular	Low regular	Premium	RON 95 E5	RON 95 E10	RON 98 E5	RON 98 E10
Name	RTCA 75.01.20:19	RTCA 75.01.19:19	Average values		EN 228:2012 + A1:2017 (Euro 6 enabling)			
Benzene Content	2.5% v/v		0.68% v/v		< 1 %v/v			
Aromatics	50% v/v		29.1% v/v		< 35 %v/v			
Olefins	30% v/v		16.3% v/v		< 18 %v/v			
Lead Content	< 0.013 g/l		< 2.5 mg/l		< 5 mg/l			
Manganese	0.25% v/v		< 0.1 mg/l		< 2.0 mg/l			
RON	> 95	> 91	**94.3**	**89.4**	> 95	> 95	> 98	> 98
MON	-		-		> 85	> 88	> 85	> 88
Sulfur Content	< 500 mg/kg		**14.6 mg/kg**		< 10 mg/kg			

Oxygen Content	2.7% v/v	-	< 2.7 %m/m	< 3.7 %m/m	< 2.7 %m/m	< 3.7 %m/m
Ethanol (EtOH)	-	0 %v/v	< 5 %v/v	< 10 %v/v	< 5 %v/v	< 10 %v/v
RVP 37.8°C (Summer)	< 69 kPa	63.8 kPa	<> 60 - 70 kPa *Depends on the country, RVP is regulated in the EU Fuel Quality Directive			
MTBE	-	0% v/v	-			
Ethers 5 or more C Atoms	-	0% v/v	Based on oxygen content	< 22 %v/v	Based on oxygen content	< 22 %v/v

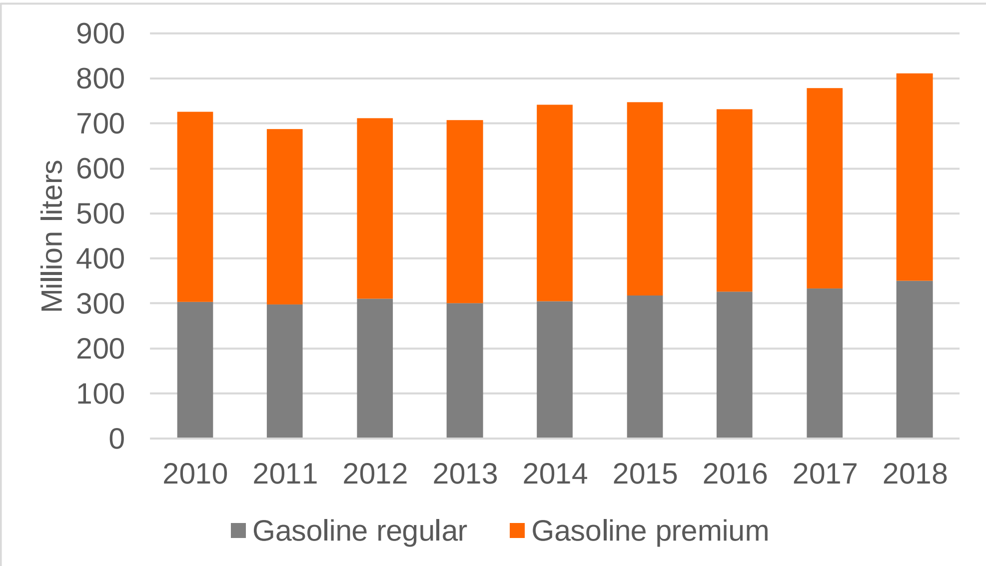
*In orange the values that would not comply with EU specifications and in blue the values that do not comply with Honduran specifications.

Source: Honduras, EU specifications and SGS Worldwide Fuel Survey, 2021

BLENDSTOCK ANALYSIS

The consumption volumes of gasoline in Honduras are shown in Figure 57. In 2018, gasoline regular amounted to 41% of the volume consumed, and gasoline premium to 59%.

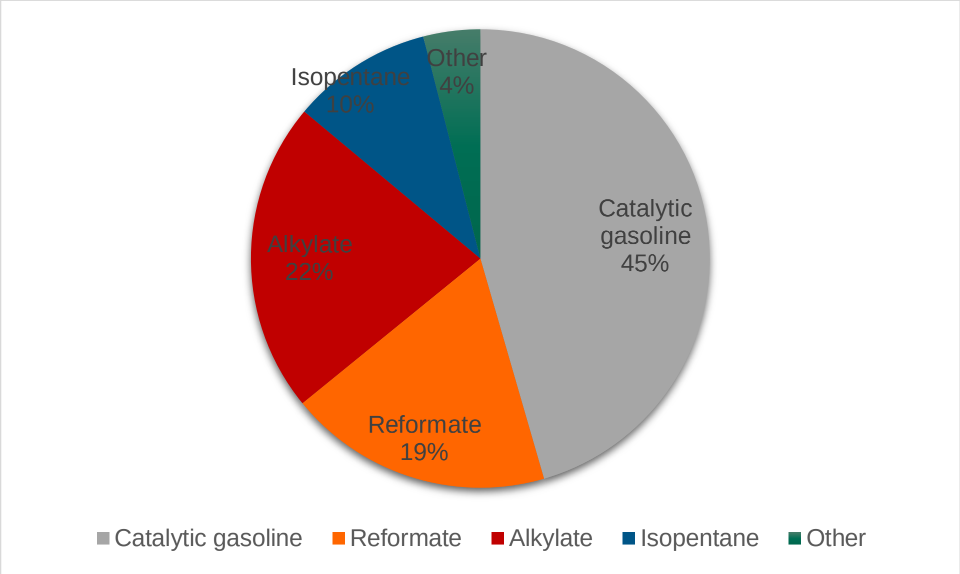
Figure 57: Consumption of gasoline in Honduras



Source: Comisión Económica para América Latina y el Caribe, Energy Secretary Honduras

Honduras' gasoline blending component mix is based mostly on U.S. imports and to a lesser extent, Ecuador, and other countries' imports.

Figure 58: Gasoline blending components produced in Honduras



Source: SGS INSPIRE Compilation

CENTRAL AMERICA: NICARAGUA

REGULATIONS

Gasoline

Nicaragua defines gasoline specifications with RTCA standards (RTCA 75.01.20:19 for gasoline premium and RTCA 75.01.19:19 for gasoline regular).

Ethanol

No domestic specifications are available in Honduras, only RTCA standards.

CURRENT FUEL QUALITY STANDARDS AND OBJECTIVES

Nicaragua has Euro 2 enabling gasoline standards. Not all properties are the same as European specifications, this comparison is mostly done according to sulfur.

Furthermore, there are no vehicle emissions standards in place.

COMPARISON AGAINST STANDARDS

Figure 59 gives an overview of this comparison about the main properties in Nicaragua and the EU. Nicaragua is the only Central American country with gasoline domestic production, and since the refinery is quite simple, Nicaragua has the poorest gasoline quality of the region.

Limits for hydrocarbons, lead, octane, sulfur, and oxygen are less strict in Nicaragua than in the EU.

Figure 59: Comparison between Nicaragua and EU specifications

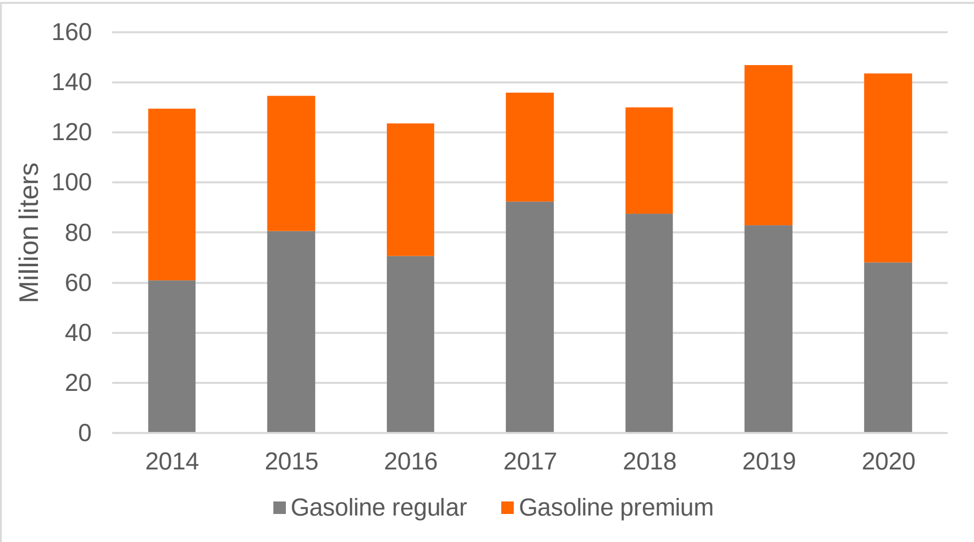
	Nicaragua		EU			
Implementation Date	2021	2021	2017			
Selected Grade	Gasoline Premium	Gasoline Regular	RON 95 E5	RON 95 E10	RON 98 E5	RON 98 E10
Name	RTCA 75.01.20:19	RTCA 75.01.19:19	EN 228:2012 + A1:2017 (Euro 6 enabling)			
Benzene Content	5% v/v		< 1 %v/v			
Aromatics	50% v/v		< 35 %v/v			
Olefins	30% v/v		< 18 %v/v			
Lead Content	< 0.013 g/l		< 5 mg/l			
Manganese	Report		< 2.0 mg/l			
RON	> 95	> 88	> 95	> 95	> 98	> 98
MON	-		> 85	> 88	> 85	> 88
Sulfur Content	< 500 mg/kg		< 10 mg/kg			
Oxygen Content	2.7% v/v		< 2.7 %m/m	< 3.7 %m/m	< 2.7 %m/m	< 3.7 %m/m
Ethanol (EtOH)	-		< 5 %v/v	< 10 %v/v	< 5 %v/v	< 10 %v/v
RVP 37.8°C (Summer)	< 69 kPa		<> 60 - 70 kPa *Depends on the country, RVP is regulated in the EU Fuel Quality Directive			
MTBE	-		-			
Ethers 5 or more C Atoms	-		Based on oxygen content	< 22 %v/v	Based on oxygen content	< 22 %v/v

Source: Nicaragua and EU specifications

BLENDSTOCK ANALYSIS

The Managua refinery in Nicaragua is the only refinery producing gasoline in Central America. Production volumes are shown in Figure 60. Local production amounts to about 30% of the local consumption of gasoline.

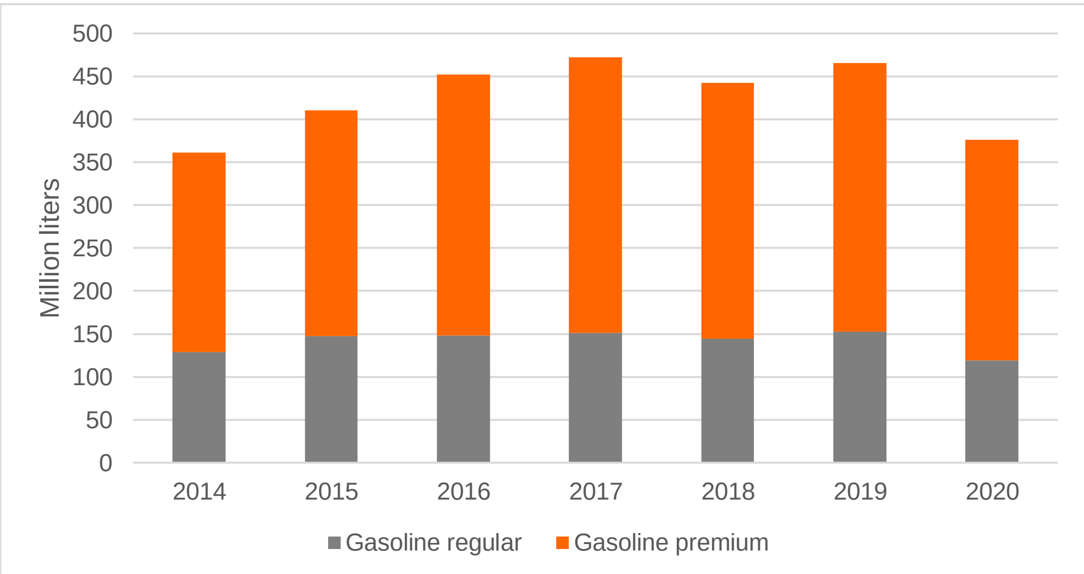
Figure 60: Production of gasoline in Nicaragua



Source: Ministry of Energy and Mines, General Directorate of Hydrocarbons, 2021

The consumption volumes of gasoline in Nicaragua are shown in Figure 61. In 2020, gasoline regular amounted to 35% of the volume consumed, and gasoline premium to 65%.

Figure 61: Consumption of gasoline in Nicaragua

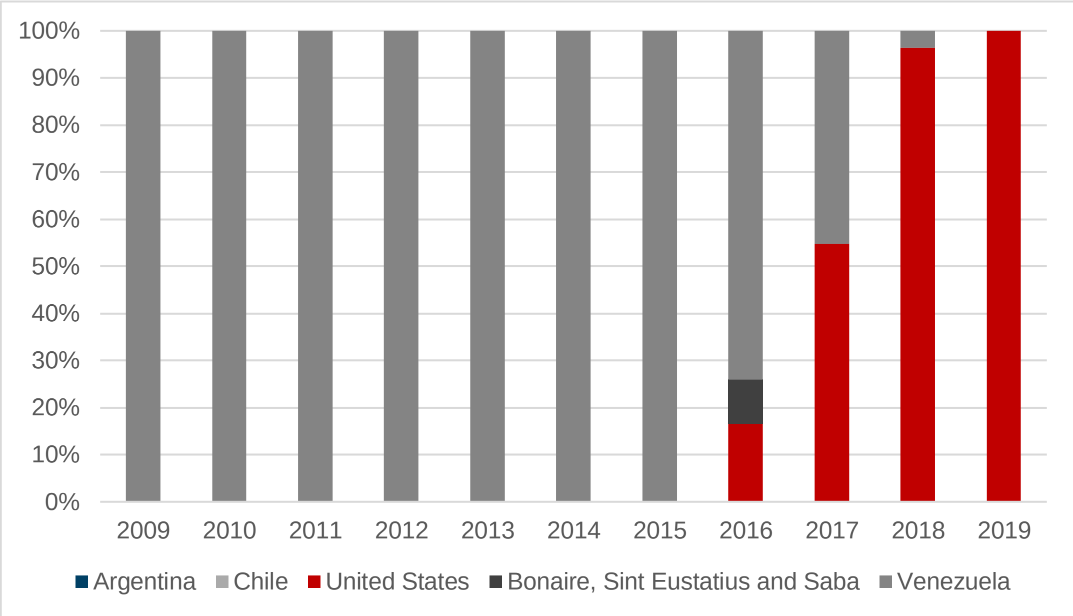


Source: Ministry of Energy and Mines, General Directorate of Hydrocarbons, 2021

In Nicaragua, as shown in Figure 62, regular gasoline was exclusively imported from Venezuela from 2009 to 2015, and from 2016 it began to be imported from the United States and from the Dutch overseas territory of Sint Eustatius. The situation changed the years after and in 2019, both regular and premium gasoline were only imported from the U.S.

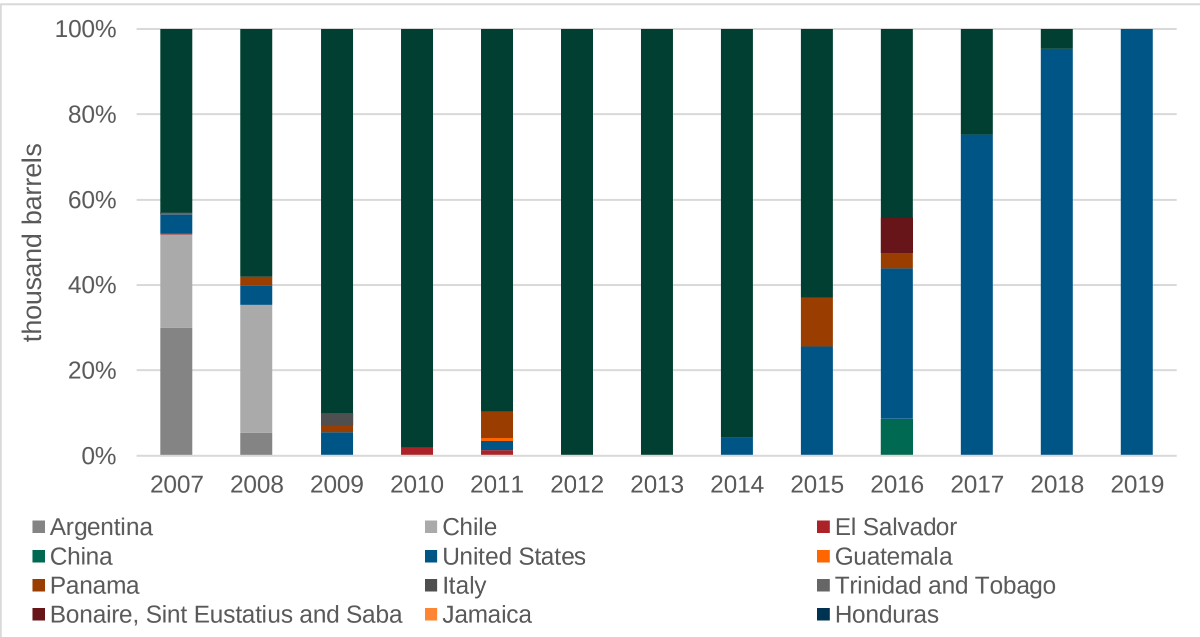
According to the Ministry of Energy and Mines, no gasoline was exported from Nicaragua in the period 2000-2016, except in 2012 when 2,000 barrels were exported.

Figure 62: Imports of regular gasoline in Nicaragua



Source: Ministry of Energy and Mines, General Directorate of Hydrocarbons, 2021

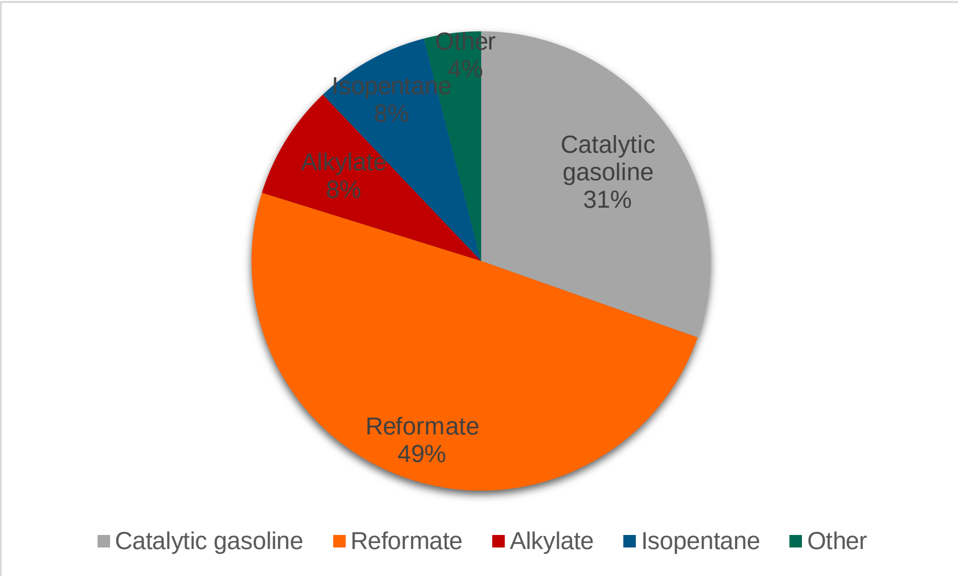
Figure 63: Imports of premium gasoline in Nicaragua



Source: Ministry of Energy and Mines, General Directorate of Hydrocarbons, 2021

Nicaragua' gasoline blending component mix is based mostly domestic production and on U.S. imports and to a lesser extent, Ecuador, and other Central American countries' imports.

Figure 64: Gasoline blending components produced in Nicaragua



Source: SGS INSPIRE Compilation

CENTRAL AMERICA: PANAMA

REGULATIONS

Gasoline

On May 6, 2013, Panama ratified the Guatemala Protocol, and the Ministry of Commerce and Industries of Panama became member of COMIECO on June 21, 2013, as stated in Resolution 309-2013. However, Panama is not a full member of SIECA, and has different national fuels specifications published by the Panamanian Commission of Industrial and Technical Standards (Comisión Panameña de Normas Industriales y Técnicas, COPANIT). The current gasoline specification is DGNTI-COPANIT 71-381-2008. Either way, Panama transposes last RTCA standards.

The specification is applicable since April 8, 2008 and defines two grades: RON 91 (referred to here as gasoline regular) and RON 95 (referred to here as gasoline premium). The only difference between the two grades is the minimum RON, all the other limits being the same. DGNTI-COPANIT 71-381-2008 sets a gradual decrease in the maximum sulfur content of gasoline, as follows.

Figure 65: Maximum sulfur content of gasoline in Panama

Date	Sulfur content (mg/kg)
May 8, 2008, to September 30, 2008	1,000
October 1, 2008, to September 30, 2009	800
October 1, 2009, to January 31, 2021	500
February 1, 2021, to present	150

Source: DGNTI-COPANIT 71-381-2008 and RTCA specifications

Furthermore, the Panamanian specifications of gasoline blended with ethanol (5 to 10% v/v) were set in the standard DGNTI-COPANIT 83-2013, approved in Resolution N°002 of May 30, 2014.

Ethanol

In Panama, the national standard DGNTI-COPANIT 82-2013 defines the specifications of anhydrous ethanol. It was approved in the Resolution N°001 of May 30, 2014.

In Panama, the ethanol content to be blended into gasoline was established in Law N°42 of April 20, 2011, at 2% v/v from April 1, 2013, with a gradual increase to 10% until April 1, 2016. The law was modified by Law N°21 of March 26, 2013, to set the ethanol content at 5% from September 1, 2013, in some regions of Panama, and from April 1, 2014, in the whole country. Law N°21 stipulates that, in the case of non-availability of domestic ethanol production, the use of gasoline with-out ethanol is allowed, with a previous approval of the National Secretariat of Energy. The ethanol mandate ended on August 22, 2014, when the National Secretariat of Energy published Resolution N° 2188 to authorize the use of gasoline without ethanol. The measure was taken after the only producer of ethanol in the country, Campos de Pesé S.A., announced it would cease to produce ethanol due to a too low Government-set ethanol sales price.

On March 4, 2021, the Panama Congress issued a bill to reform Law 42 of 2011 to implement the use of anhydrous ethanol as oxygenate in gasoline and establish an ethanol production industry in the country.

Panama is planning to produce ethanol with sugarcane. The ethanol plants will be constructed close to the sugar mills to take advantage of their already established infrastructure and economies of scale.

Even though the government wants to build a domestic ethanol production industry, the document also envisages benefits of using imported alcohol for the production of ethanol:

- To import ethanol from consolidated industries, such as Brazil or the United States, would reduce the average price of ethanol that will be mixed with gasoline in Panama, so that there is no impact on the consumer
- Establishing the ethanol industry in Panama from sugarcane will require a huge effort that involves many local actors. Importing ethanol would help develop the program at its own pace
- The sugarcane harvest takes place from January to April, to produce fuel ethanol from imported alcohol would help mitigate the effect of the seasonality of the sugarcane harvest period
- Panama could become a strategic point for the storage and distribution of alcohols in the region

In conclusion, with the current installed capacity of 4 sugar mills, more than 1,500,000 tons of sugarcane in addition to those currently processed could be handled, which means that more than 18,000 additional hectares could be sown. This would allow the production of more than 110 million liters of ethanol.

The ethanol blend mandate schedule is planned to be as follows:

Figure 66: Ethanol blend mandate schedule according to Bill

Date	Blend mandate	Locations
April 1, 2023	5%	Province of Panama, to the north up to Chagres river, to the east up to the area of 24 of December, to the west up to the Panama Channel. In the Province of Panama West in the districts of La Chorrera and Arraiján
April 1, 2024	5%	Nationwide
April 1, 2025	7%	Nationwide
April 1, 2026	10%	Nationwide

Source: Bill to update Law 42 of 2011

The 10% v/v ethanol blend in anhydrous ethanol may be increased by the National Energy Secretariat based on technological advances. The fuels that might be allowed to blend with ethanol might be expanded as well. Moreover, the National Energy Secretariat may authorize the use of other biofuels, such as hydrated ethanol.

In the event that the ethanol blend mandates, deadlines, or geographical areas established cannot be met, the National Energy Secretariat may modify them. Also, if there is no availability of domestic ethanol, the National Energy Secretariat may allow the use of gasoline without ethanol.

CURRENT FUEL QUALITY STANDARDS AND OBJECTIVES

Panama domestic gasoline specifications are Euro 2 enabling standards, and current enforced RTCA specifications are Euro 3 enabling standards. Not all properties are the same as European specifications, this comparison is mostly done according to sulfur.

Furthermore, there are no vehicle emissions standards in place.

COMPARISON AGAINST STANDARDS

Figure 67 gives an overview of the comparison about the main properties in Panama and the EU. The actual quality is more similar to EU specifications than Central American specifications, which means that gasoline has been improving in the past years.

Limits for hydrocarbons, lead, octane, sulfur, and oxygen are less strict in Panama than in the EU.

Actual quality of gasoline in Panama meets Panama and EU specifications, except for octane, which is lower than what the regulation requires and sulfur, which is higher than what is required in the EU.

Actual quality shown in the table is the average values of 8 samples: 4 samples of regular RON 91 and 4 samples of premium RON 95 collected in Santa Clara, San Cristóbal, and Vista Hermosa.

Figure 67: Comparison between Panama and EU specifications and actual quality data

	Panama		**Panama actual gasoline quality from 2019/2020 winter SGS WWFS Average**		**EU**			
Implementation Date	2014/2021		-		2017			
Selected Grade	RON 91	RON 95	Regular 91	Premium 95	RON 95 E5	RON 95 E10	RON 98 E5	RON 98 E10
Name	DGNTI-COPANIT 83-2013/ Resolution 425/2020		Average values		EN 228:2012 + A1:2017 (Euro 6 enabling)			
Benzene Content	< 5% v/v / <1.5% v/v		0.71% v/v		< 1 %v/v			
Aromatics	< 50% v/v		30.8% v/v		< 35 %v/v			
Olefins	< 30% v/v		15.9% v/v		< 18 %v/v			
Lead Content	< 0.013 g/l		< 2.5 mg/l		< 5 mg/l			
Manganese	-		5 mg/kg		< 2.0 mg/l			
RON	> 91	> 95	**90.6**	**94.4**	> 95	> 95	> 98	> 98
MON	-	-	-		> 85	> 88	> 85	> 88
Sulfur Content	< 500 mg/kg / < 150 mg/kg		**29.0**		< 10 mg/kg			
Oxygen Content	-/ < 0.7% v/v		-		< 2.7 %m/m	< 3.7 %m/m	< 2.7 %m/m	< 3.7 %m/m
Ethanol (EtOH)	10% v/v		0% v/v		< 5 %v/v	< 10 %v/v	< 5 %v/v	< 10 %v/v
RVP 37.8°C (Summer)	< 69 kPa (< 76 kPa if ethanol is added)		61.8 kPa		<> 60 - 70 kPa *Depends on the country, RVP is regulated in the EU Fuel Quality Directive			
MTBE	0% v/v if ethanol is added		0% v/v		-			
Ethers 5 or more C Atoms	-		0% v/v		Based on oxygen content	< 22 %v/v	Based on oxygen content	< 22 %v/v

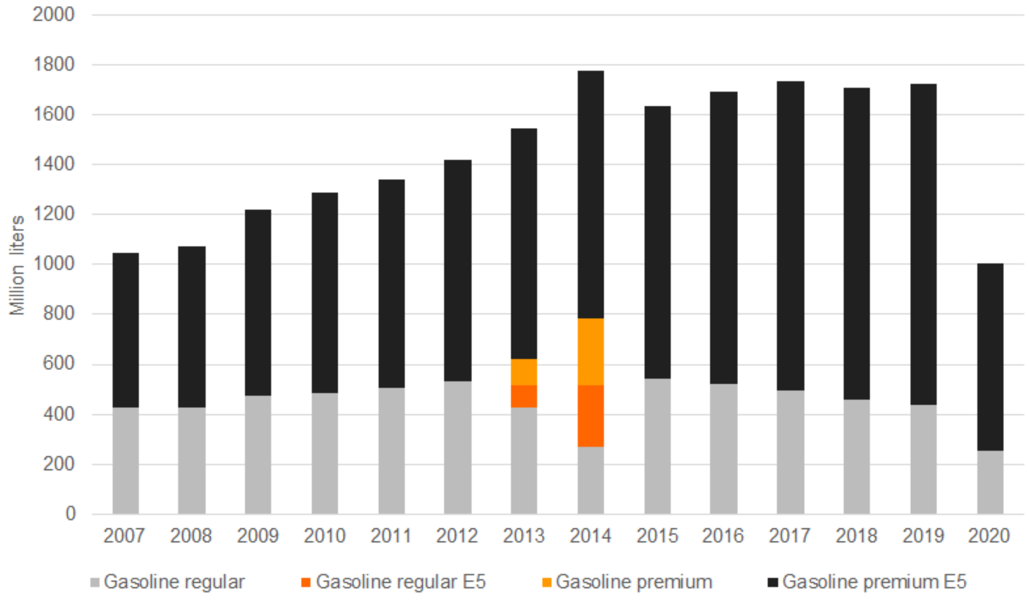
*In orange the values that would not comply with EU specifications and in blue the values that do not comply with Panamanian specifications.

Source: Panama and EU specifications, SGS Worldwide Fuel Survey, 2021

BLENDSTOCK ANALYSIS

The consumption volumes of gasoline in Panama are shown in Figure 68. In 2020, gasoline regular amounted to 30% of the volume consumed, and gasoline premium to 70%. Gasoline blended with 5% volume ethanol (E5) was only consumed during the years 2013 and 2014, when the ethanol mandate was enforced.

Figure 68: Consumption of gasoline in Panama



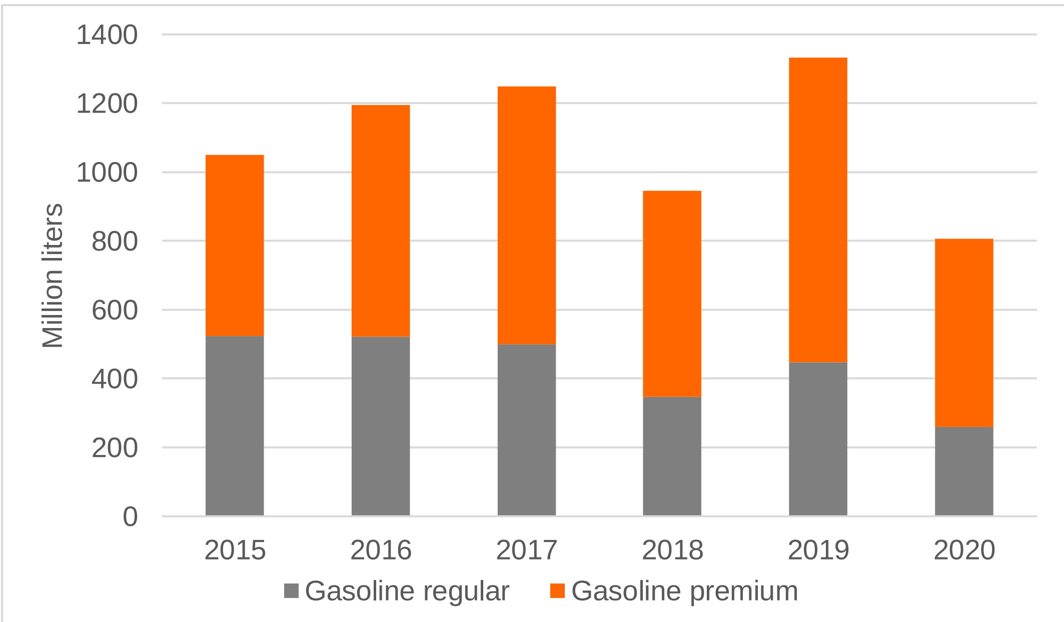
Source: National Energy Secretariat, 2021

The volumes of imported gasoline in Panama are shown in the figure below.

Furthermore, SGS SOL data indicate almost 784 million liters of gasoline imported by the different terminals, 713 million liters of gasoline with no grade specified, 54 million liters of premium and 18 million liters of regular.

According to United Nations Comtrade, imports came from the United States, Netherlands, and Germany mostly in 2017 (last year of data).

Figure 69: Imports of gasoline in Panama

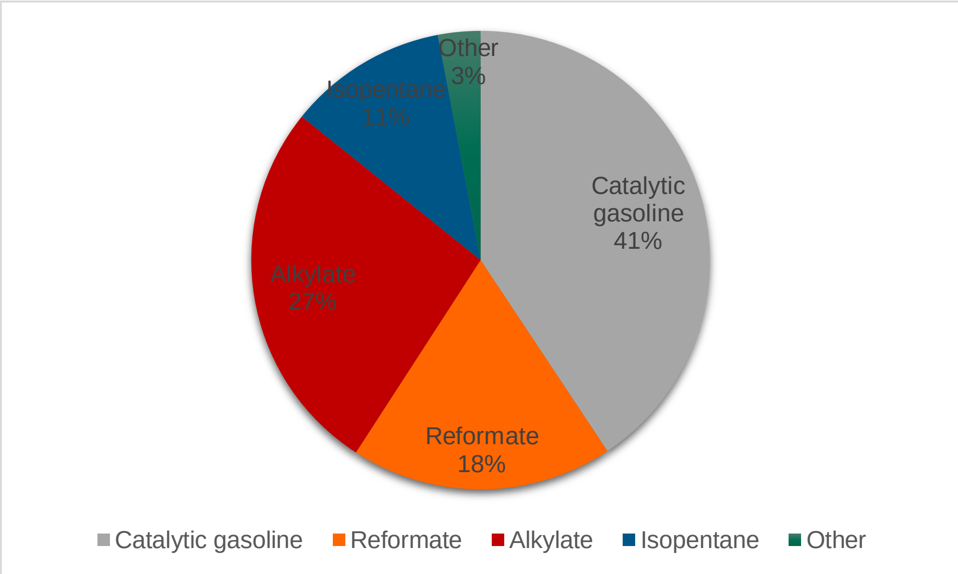


Source: National Institute of Statistics and Census, 2021

From the Central American countries, only Nicaragua and Costa Rica have refining capacity, however Costa Rica is not producing any fuels at present.

Panama' gasoline blending component mix is based mostly on U.S. imports and to a lesser extent, Ecuador, and other countries' imports.

Figure 70: Gasoline blending components produced in Panama



Source: SGS INSPIRE Compilation

CHILE

REGULATIONS

Gasoline

Current gasoline specifications in the metropolitan region of Santiago are defined in the Decree 66, 2010, and have been applicable since April 2010. This Decree stipulates not only fuel specifications but also vehicle emissions standards, as it is an integral policy aiming at improving air quality in Santiago. The specific characteristics of the metropolitan region of Santiago regarding its orography and climate means that pollutants are more concentrated than in other parts of the country, especially during the autumn-winter season.

National and regional specifications that currently apply in the rest of the country were set by Decree 60, 2012, published in March 2012.

Decree 66, 2010 enforced mandatory specifications for gasoline grade sold in the metropolitan region with 15 ppm sulfur limit. The main characteristics of the gasoline sold in the metropolitan region are shown in the following table:

Figure 71: Gasoline specifications in Chile, Decree 66/2010

Parameter	Limit and unit	Test Method
Sulfur, maximum	15 mg/kg	ASTM D 5453, ASTM D 7039, ASTM D 2622
Oxygen, maximum	2%wt	ASTM D 6293, ASTM D 4815
Reid Vapor Pressure (RVP), maximum	55 and 69 kPa (1)	ASTM D 323, ASTM D 4953, ASTM D 5191
Olefins, maximum	12%v/v	ASTM D 6293, ASTM D 1319, ASTM D 6839
Aromatics, maximum	38%v/v	ASTM D 6293, ASTM D 1319, ASTM D 6839
Benzene, maximum	1%v/v	ASTM D 4053, ASTM D 3606, ASTM D 5580

(1) 55 kPa from September 1 to March 31 and 69 kPa from April 1 to August 31

Source: Chilean specifications

Parameters not included in Decree 66, 2010 are regulated according to Chilean standard NCh 64:1995.

Decree 60, 2012, published two years later, intended to harmonize specifications of other parts of the country with those set for the metropolitan region of Santiago.

The main differences in specifications from 2012 compared to Decree 66, 2010, are: the olefins content (20%v/v instead of 12%v/v) and the Reid vapor pressure (RVP) of 83 kPa for two regions: Magallanes and the Chilean Antarctic, instead of 69 kPa applicable in the rest of the regions.

Ethanol

Ethanol (E100) is not used as a neat fuel, neither is it blended with gasoline. Nevertheless, Decree 11, 2008, defines quality specifications for ethanol and biodiesel.

CURRENT FUEL QUALITY STANDARDS AND OBJECTIVES

Chilean fuel quality specifications are similar to Euro 5 enabling specifications. Not all properties are the same as European specifications, this comparison is mostly based on sulfur limits.

Furthermore, vehicle emissions standards in Chile are Euro 5 for light-duty vehicles and Euro V for heavy-duty vehicles.

COMPARISON AGAINST STANDARDS

Specifications of gasoline in Chile are similar to European specifications enabling Euro 6 emission standards. Figure 72 presents this comparison for the main properties and actual gasoline quality in winter 2020-2021. As can be seen, actual quality of gasoline in Chile satisfies the Chilean and European specifications, with the exception of octane number (RON and MON) that for Premium and Premium Plus grades are slightly lower than European requirement of 95.

Another difference is that Chile does not use ethanol, but MTBE.

Actual quality shown is the average values of 8 samples obtained in Santiago and Antofagasta, 2 samples of RON 93, 4 samples of RON 95 and 2 samples of RON 97.

Figure 72: Comparison between Chilean and EU specifications

	Chile		**Chile actual gasoline Winter quality SGS WWFS 2020/2021 Average**		**EU**			
Implementation Date	2012/2010		N/A		2017			
Selected Grade	Gasoline	Gasoline metropolitan region	Premium	Premium plus	RON 95 E5	RON 95 E10	RON 98 E5	RON 98 E10
Name	Decree 60, NCh 64	Decree 66, 2010	Average values		EN 228:2012 + A1:2017 (Euro 6 enabling)			
Benzene Content	< 1 %v/v		0.61% v/v		< 1 %v/v			
Aromatics	< 38 %v/v		28.9% v/v		< 35 %v/v			
Olefins	20 %v/v	12 %v/v	9.1% v/v		< 18 %v/v			
Lead Content	< 0.013 g/l		< 2.5 mg/l		< 5 mg/l			
Manganese	Report		< 0.1 mg/kg		< 2.0 mg/l			
RON	-		**93.8**	**96.4**	> 95	> 95	> 98	> 98
MON	-		**84.5**	**85.7**	> 85	> 88	> 85	> 88
Sulfur Content	< 15 mg/kg		6 mg/kg		< 10 mg/kg			
Oxygen Content	< 2 %m/m		-		< 2.7 %m/m	< 3.7 %m/m	< 2.7 %m/m	< 3.7 %m/m
Ethanol (EtOH)**	-		0 mg/kg		< 5 %v/v	< 10 %v/v	< 5 %v/v	< 10 %v/v
RVP 37.8°C (Summer)	<> 69 kPa <> 83 kPa (Magallanes and Antarctic Region)	<> 55 kPa	-		<> 60 - 70 kPa *Depends on the country, RVP is regulated in the EU Fuel Quality Directive			
RVP 37.8°C (Winter)	<> 45 - 80 kPa	<> 69 kPa	52.4 kPa					
Ethers 5 or more C Atoms	-		10.15% v/v (MTBE)		Based on oxygen content	< 22 %v/v	Based on oxygen content	< 22 %v/v

*In orange the values that would not comply with EU specifications and in blue the values that do not comply with Chilean specifications.

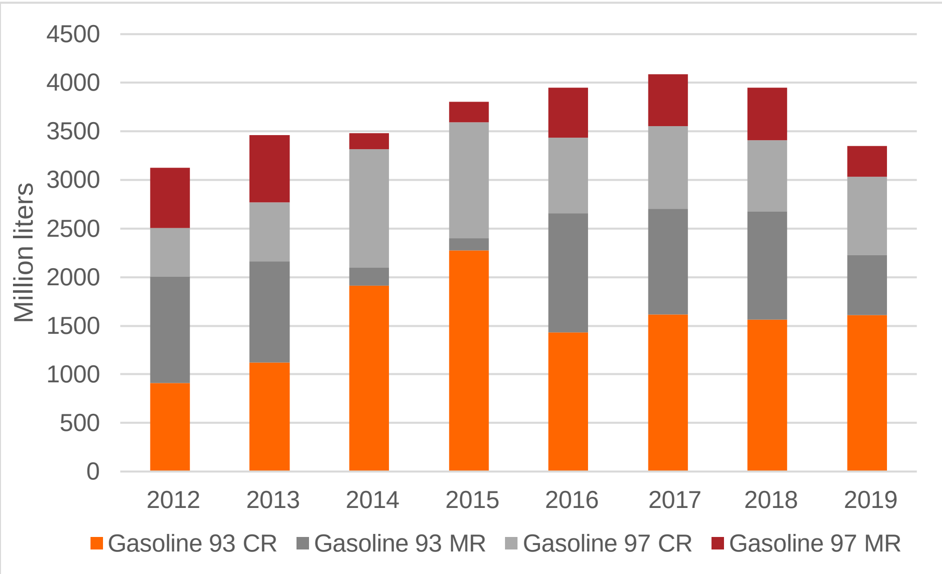
**Ethanol is allowed up to 5% v/v in Chile according to Decree 11, 2008.

Source: Chilean and EU specifications, SGS Worldwide Fuel Survey, 2021

BLENDSTOCK ANALYSIS

Production of total gasoline in Chile has been maintained at approximately between 3,000 and 4,000 million liters per year since 2012. Gasoline production reached more than 4,000 million liters in 2017 but decreased to 3,400 million liters in 2019.

Figure 73: Gasoline production in Chile, per grade and refinery

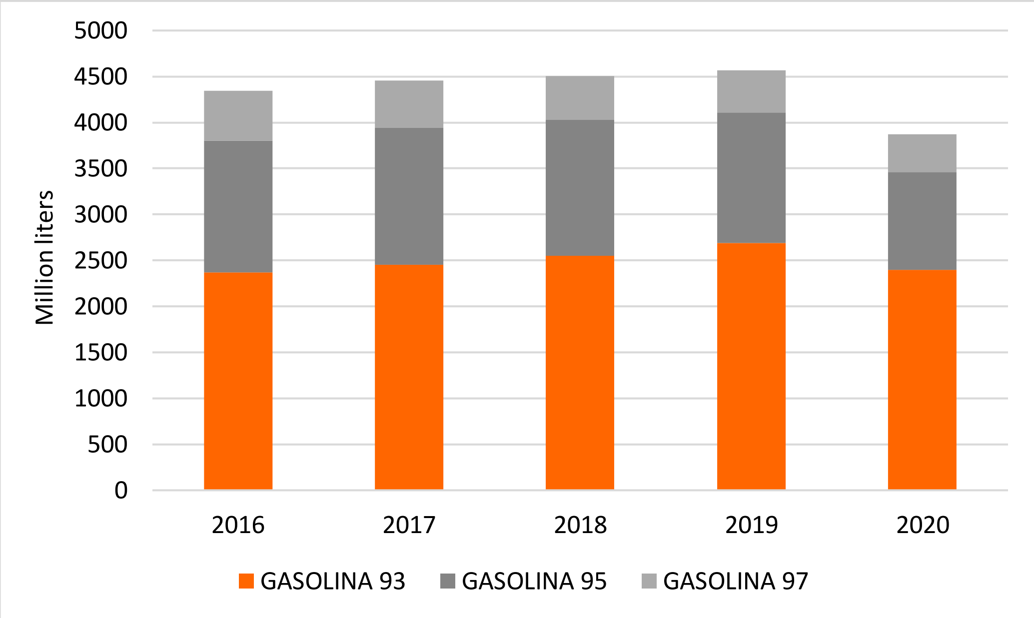


MR: Metropolitan region
CR: Rest of the country

Source: National Energy Commission, Chile

In 2020 gasoline sales by grade in Chile were as follows: 62% gasoline RON 93, 28% gasoline RON 95 and 11% gasoline RON 97. Gasoline RON 95 is produced by blending of gasoline RON 93 and gasoline RON 97.

Figure 74: Gasoline demand in Chile per octane grade

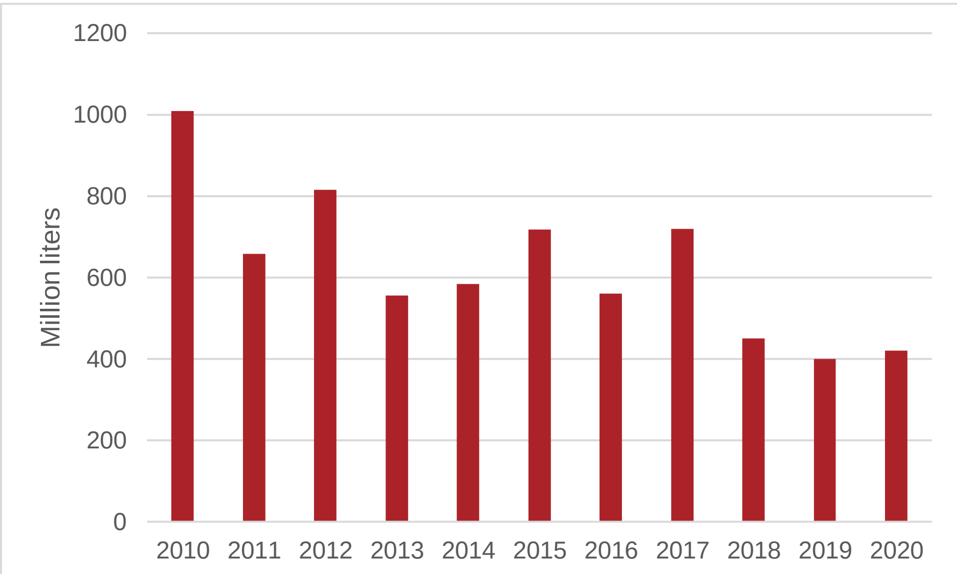


Source: Department of Electricity and Fuels, 2021

Gasoline demand is higher than gasoline production in Chile. In 2020, gasoline demand was 10% higher than gasoline production. This is why Chile needs gasoline imports, which were at their highest in 2017 in the past 5 years but decreased in 2018.

Data extracted from the SGS Shipping Online (SOL) service indicate 1043 million liters imported by Chile from April 2020 to April 2021. From this amount, 708 million liters were finished gasoline with undetermined octane, 196 million liters - gasoline RON 93, 65 million liters - gasoline RON 84, 64 million liters - MTBE and 9 million liters - reformate. These data conclude that almost all gasoline imported is a finished product and that gasoline is re-exported from Chile to other countries.

Figure 75: Gasoline imports to Chile, 2010-2020



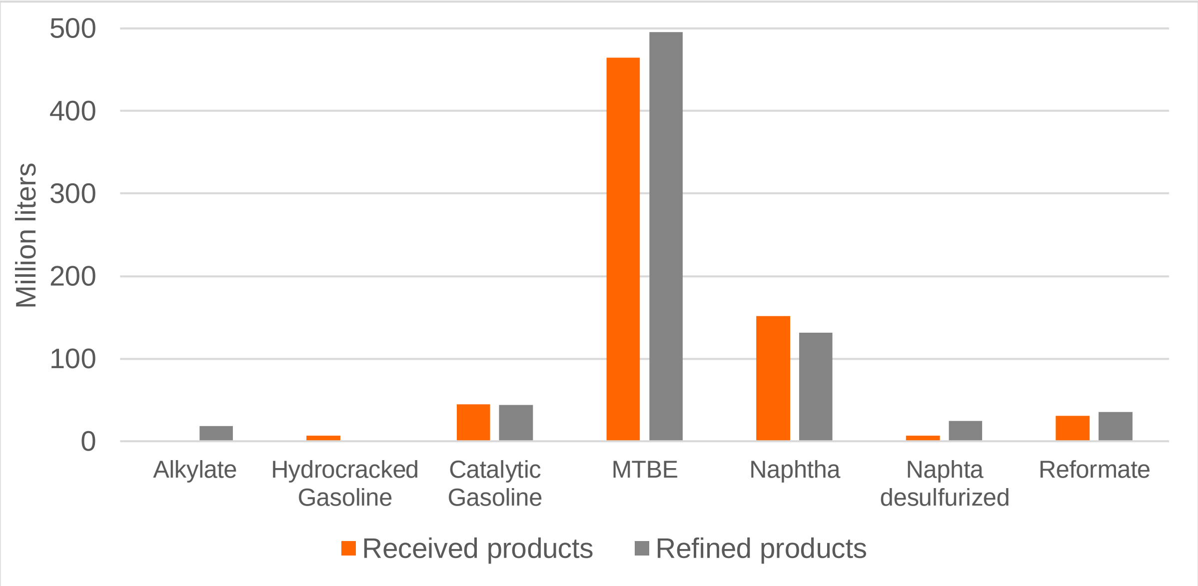
Source: National Energy Commission, Chile

According to the United Nations Comtrade, gasoline imports into Chile come from Europe and the U.S.

According to Energía Abierta Chile, 9% of the gasoline imported in 2021 was originated from Spain and 91% of the gasoline came from the U.S. Furthermore, according to SGS SOL, most gasoline is imported by ENAP, National Oil Company from Chile.

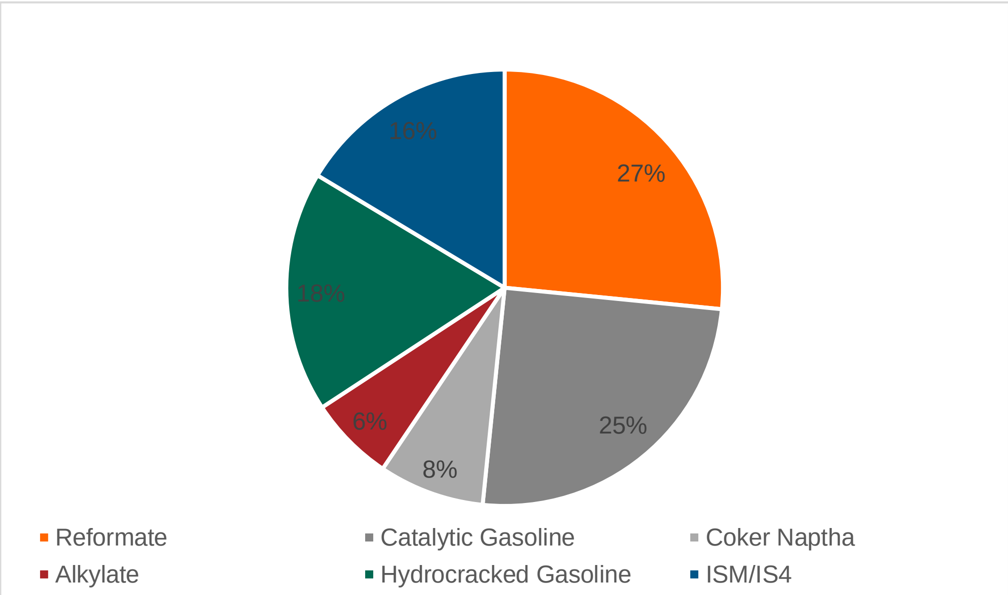
MTBE is the most produced gasoline component, followed by naphtha and catalytic gasoline but their production is significantly lower. Alkylates are not produced but received by ENAP from imports. However, the blend of components to produce gasoline is mostly based on reformate, catalytic gasoline, and hydrocracked gasoline, as shown in the figure below.

Figure 76: Processed products in the Chilean refineries



Source: Ministry of Energy of Chile, 2021

Figure 77: Processed products in the Chilean refineries except for MTBE



Source: *HCX with Wood Mackenzie PennEnergy Research and Oil and Gas Journal data*

COLOMBIA

REGULATIONS

Gasoline

Current gasoline specifications are defined in Resolution 1180, 2006 from June 21, 2006, which superseded Resolution 1565/2004 from December 27, 2004, and Resolution 1289/2005 from September 7, 2005. Resolution 1180, 2006 established targets to reduce sulfur limits in gasoline by 2010, and gasoline specifications have not been modified since then.

Currently there are four gasoline grades on the market:

- Non-oxygenated gasoline regular grade
- Non-oxygenated gasoline extra grade
- Oxygenated gasoline regular grade
- Oxygenated gasoline extra grade

Most gasoline sold in Colombia is oxygenated E10 grade; gasoline E0 is only consumed in the provinces bordering Venezuela, where a great deal of smuggling happens, and in much lower volumes than E10.

The differences in properties between the regular and extra grades are anti-knock index (AKI), benzene and aromatics.

Figure 78: Main differences between gasoline grades in Colombia

Property	E0 regular	E0 extra	E10 regular	E10 extra
AKI	81	87	84	89
Aromatics (% vol.)	28	35	25	31.5
Benzene (% vol.)	1.0	2.0	0.9	1.8

Source: Resolution 1180, 2006

In 2018, several ministries approved a document setting a timeframe to improve air quality. In this document, called CONPES 3943 and published by the National Council of Economic and Social Policy of Colombia, a schedule to upgrade fuel quality in term of sulfur is released. For gasoline, this schedule is as follows:

Figure 79: Timeframe for sulfur reduction in gasoline in Colombia

Timeline	Sulfur in gasoline
May 2021	100 ppm
December 2021	50 ppm
2026-2030	10 ppm

Source: CONPES 3943

On April 7, 2021, Colombia's Ministry of Mines and Energy and the Ministry of Environment and Sustainable Development issued Resolution 40103 to modify the specifications for biodiesel, diesel, gasoline, and oxygenated gasoline, and to implement renewable diesel specifications. This Resolution was first announced as a bill in December 2020.

The main changes introduced by this Resolution became official after its publication in the Official Journal, on April 7, 2021. However, fuels compliant with old specifications can remain on the market for six months longer or until stocks are finished.

Figure 80: Changes for gasoline incorporated in the Resolution 40103

	Current	As of May 1, 2021	As of April 7, 2021	As of December 31, 2021	Until December 30, 2030	Up to December 31, 2030
Regular Gasoline (Gasoline Corriente)						
RON	AKI 81		AKI 81		84	88
Sulfur (mg/kg)	300	100		50		10
Aromatics (% v/v)	28				28	35
Premium Gasoline (Gasoline Extra)						
RON	AKI 87		RON 93			
Sulfur (mg/kg)	300	100		50		10
Aromatics (% v/v)	35	35				35

Source: Resolution 40103, 2021 on gasoline quality

Figure 81: Changes for oxygenated gasoline incorporated in the Resolution 40103

	Current	As of May 1, 2021	As of April 7, 2021	As of December 31, 2021	Until December 30, 2030	Up to December 31, 2030
Regular Gasoline (Gasoline Corriente)						
RON	AKI 84		AKI 84		89	92
Sulfur (mg/kg)	270	90		50		10
Aromatics (% v/v)	25				25	31.5
Premium Gasoline (Gasoline Extra)						
RON	AKI 89		97			
Sulfur (mg/kg)	270	90		50		10
Aromatics (% v/v)	31.5	31.5				

Source: Resolution 40103, 2021 on gasoline quality

The 2020 Bill implemented a new schedule for reducing sulfur in the whole gasoline pool to 10 mg/kg, which has been slightly modified in the final version of the law, i.e., Resolution 40103 of 2021. 10 mg/kg will be finally achieved in 2031.

Another interesting change is the incorporation of the RON parameter; until now, only AKI was required. The difference in RON between regular gasoline and premium gasoline is significant, both for non-oxygenated and oxygenated gasoline. Furthermore, RON will be quite low compared to international standards.

Ethanol

Ethanol (E100) is not used as a neat fuel, but it is blended with gasoline up to 10% v/v. Resolution 789/2016, defines anhydrous ethanol specifications in Colombia; normal and denatured.

Ethanol blending in gasoline in Colombia began with Law 693/2001, which established that ethanol blending in gasoline should be mandatory in all cities with more than 500,000 inhabitants. The reason behind the implementation of ethanol blending was related with the policy to improve air quality in large cities and promotion of the agro-industry in the country.

Law 693/2001 established norms to use ethanol fuel and promoted its production, supply and consumption. The following table shows the most important legislation for ethanol in Colombia, including ethanol blending mandates.

Figure 82: Legislation related to ethanol mandates in Colombia

Law/Resolution	Content
Law 693/2001 from September 19, 2001	E10 in cities with more than 500,000 inhabitants
Decree 1135 from March 31, 2009	Increase of E85 vehicles in Colombia
Resolution 90932 from October 31, 2013	E10 blending in regular and extra grades
Resolution 41072 from October 1, 2015	E10 blending mandate in southwest area
Resolution 40434 from May 18, 2017	Blend mandate was suspended in some areas
Resolution 40626 July 4, 2017	E8 blending mandate in regular grade
Resolution 40185 from February 27, 2018	Back to E10 blending mandate in regular and extra grades
Further changes	Several changes due to COVID-19 pandemic
Resolution 40111 from April 9, 2021	E10 except for some provinces with E5
Resolution 40261 from August 12, 2021	Delays for re-introduction of E10 in several provinces

Source: Fedebiocombustibles, Ministry of Energy and Mines of Colombia

The last time the government modified the ethanol blend mandate was with Resolution 40261 from August 12, 2021. Stoppages in several ethanol producing plants forced the government to reduce the ethanol blend mandate in certain provinces. The ethanol blend mandate will correspond to the levels shown in Figure 83.

Figure 83: Dates of enforcement of ethanol blend mandates nationwide and in certain provinces

Enforcement date	Departments with exceptions	Ethanol blend mandate
September 2021	Nationwide with exceptions	6%
October 2021		6%
November 2021		6%
December 2021		8%
January 2022 onwards		10%
August 2021	Arauca, Guainía, La Guajira, Vaupés and Vichada	2%
October 2021		5%
April 2022 onwards		10%
August 2021	San Andrés, Providencia, Santa Catalina, Norte Santander, City center of Río de Oro	0%
July 2022		5%
January 2023 onwards		10%

Source: Resolution 40261, August 12, 2021

CURRENT FUEL QUALITY STANDARDS AND OBJECTIVES

Specifications of gasoline in Colombia differ from the European specifications enabling Euro 6 emission standards, currently in force. Colombia enforces Euro 2 enabling fuel standards, but Euro I-4 light-duty vehicle emissions standards and Euro IV heavy-duty vehicle emissions standards.

COMPARISON AGAINST STANDARDS

Figure 84 presents the comparison for the main properties set out in the Colombia's specifications, current EU specifications and the actual quality of winter gasoline in 2020-2021, according to SGS Worldwide Fuel Survey. The most significant differences are RON, MON, and sulfur quality. Average ethanol content is below the 10% v/v ethanol blend mandate, and sulfur is below Colombian specifications but not EU specifications.

Actual quality shown is the average values of 8 samples obtained in Bogotá, Cartagena and Medellín, 4 samples of regular and 4 samples of premium gasoline.

Figure 84: Comparison between Colombian and EU specifications and actual quality

	Colombia		**Colombia actual gasoline Winter quality 2020/2021 Average**		**EU**			
Implementation Date	2006		N/A		2017			
Selected Grade	Gasoline Regular Oxygenated	Gasoline Extra Oxygenated	Regular	Premium	RON 95 E5	RON 95 E10	RON 98 E5	RON 98 E10
Name	Resolution 1180, 2006		Average values		EN 228:2012 + A1:2017 (Euro 6 enabling)			
Benzene Content	< 0.9 %v/v	< 1.8 %v/v	0.41% v/v		< 1 %v/v			
Aromatics	< 25 %v/v	< 31.5 %v/v	17.3% v/v		< 35 %v/v			
Olefins	-		15% v/v		< 18 %v/v			
Lead Content	< 0.013 g/l		< 2.5 mg/l		< 5 mg/l			

Manganese	-		0 mg/kg		< 2.0 mg/l			
RON	-		91.5	98.6	> 95	> 95	> 98	> 98
MON	-		81.9	87.0	> 85	> 88	> 85	> 88
AKI	> 84	> 89	86.7	92.8	-			
Sulfur Content	< 270 mg/kg		31.8		< 10 mg/kg			
Oxygen Content	< 3.5 %m/m		-		< 2.7 %m/m	< 3.7 %m/m	< 2.7 %m/m	< 3.7 %m/m
Ethanol (EtOH)	<> 9.5 - 10.5 %v/v		9.33% v/v		< 5 %v/v	< 10 %v/v	< 5 %v/v	< 10 %v/v
RVP 37.8°C	<> 65 kPa		58.9 kPa		<> 60 - 70 kPa *Depends on the country, RVP is regulated in the EU Fuel Quality Directive			
Ethers 5 or more C Atoms	-		0 kPa		Based on oxygen content	< 22 %v/v	Based on oxygen content	< 22 %v/v

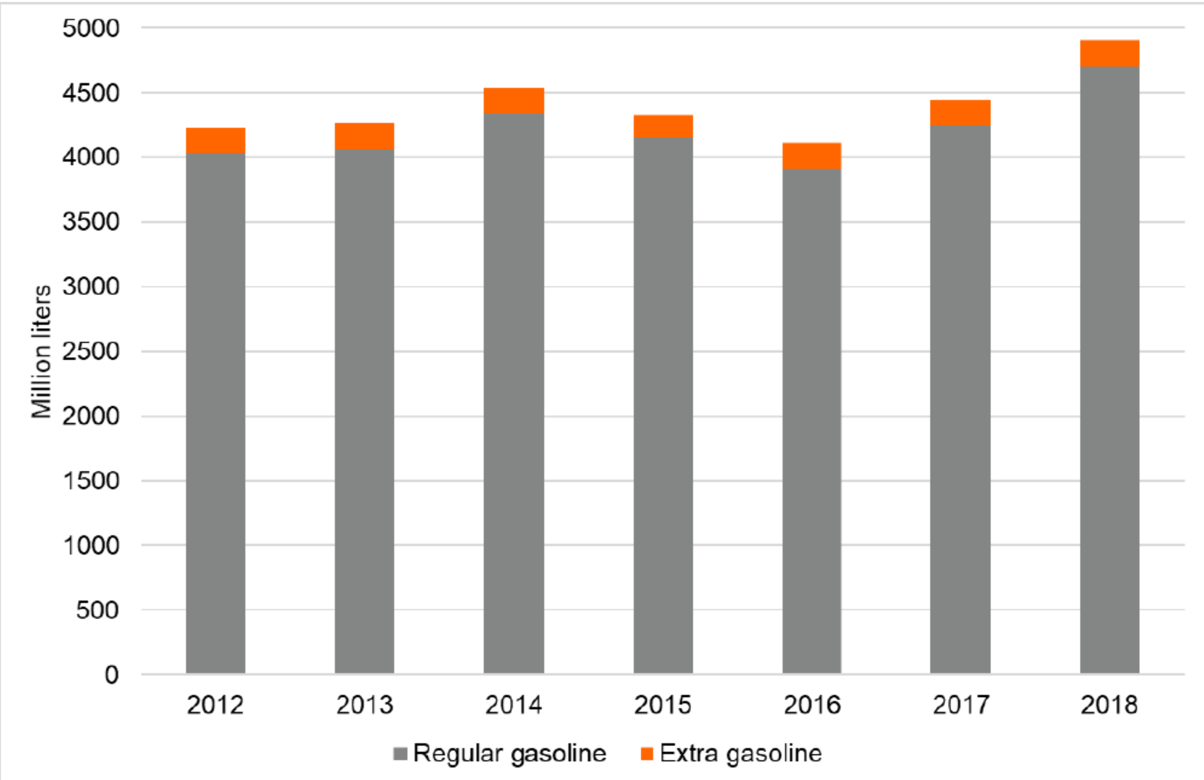
*In orange the values that would not comply with EU specifications and in blue the values that do not comply with Colombian specifications.

Source: Colombian and EU specifications, SGS Worldwide Fuel Survey, 2021

BLENDSTOCK ANALYSIS

Production of total gasoline in Colombia has been maintained at between 4000 and 5000 million liters per year, with a market share of approximately 5% of extra gasoline (AKI 87) and 95% of regular gasoline (AKI 81).

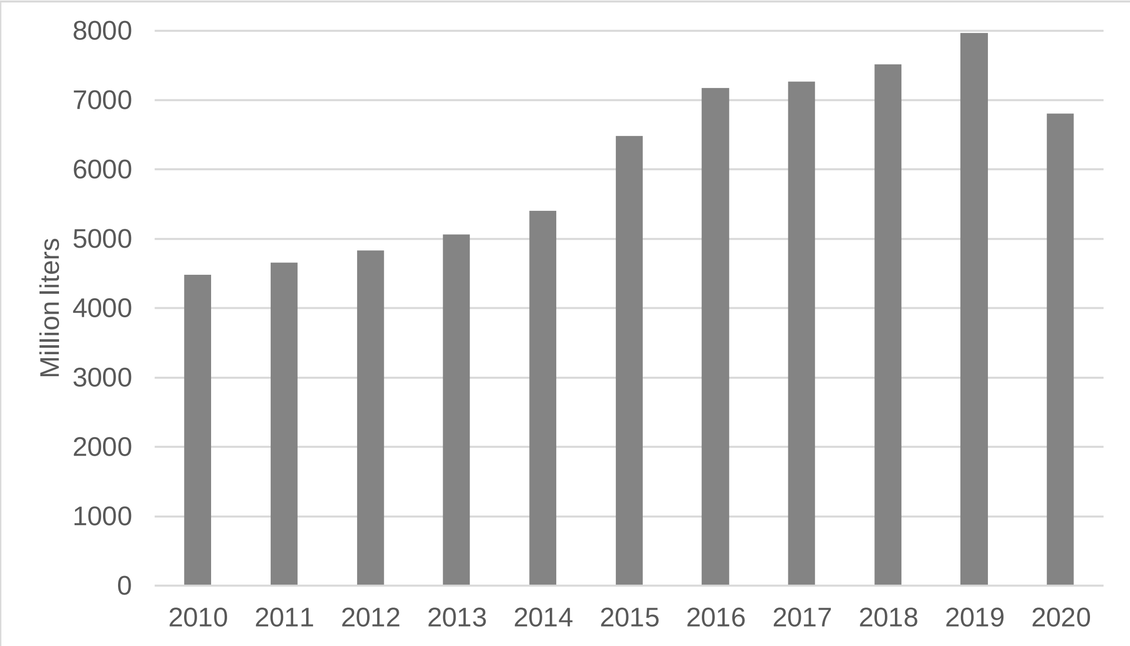
Figure 85: Non-Oxygenated gasoline production in Colombia per octane grade



Source: Unit of Mining and Energy Planning

Gasoline demand is higher than gasoline production in Colombia. From 2012 to 2020, gasoline demand was 30% higher than gasoline production.

Figure 86: Non-Oxygenated gasoline demand in Colombia

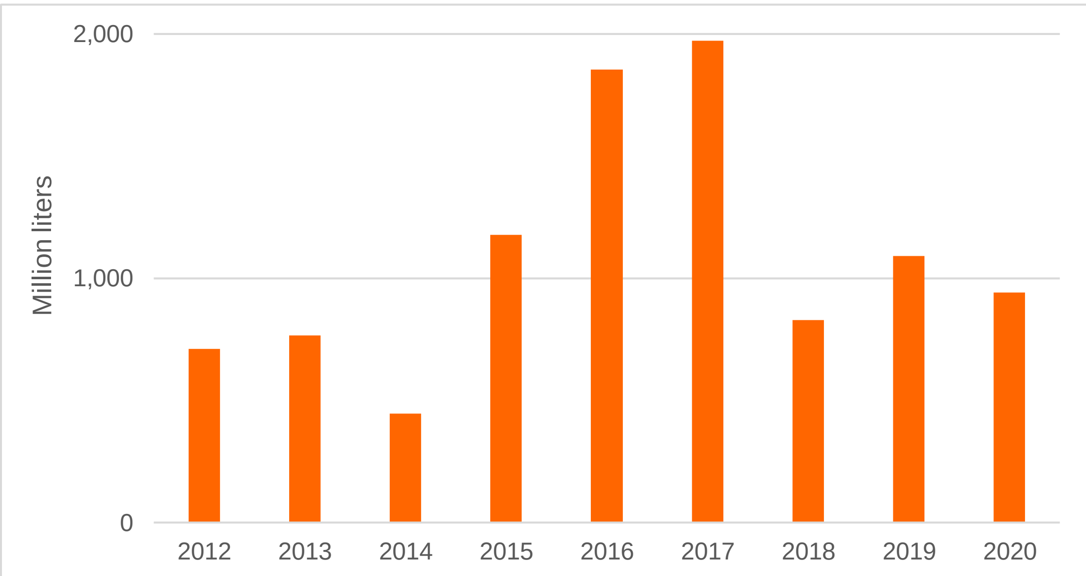


Source: Unit of Mining and Energy Planning, ECOPETROL

Colombia needs gasoline imports, which were at their highest during 2016-2017, but decreased in 2018.

Data extracted from the SGS SOL system indicate that 800 million liters were imported by Colombia from April 2020 to April 2021. From this amount, 778 million liters were finished gasoline with no grade determined and 20 million liters were gasoline RON 83. Colombia imports mainly from the United States according to the United Nations Comtrade.

Figure 87: Gasoline imports to Colombia, 2012-2020

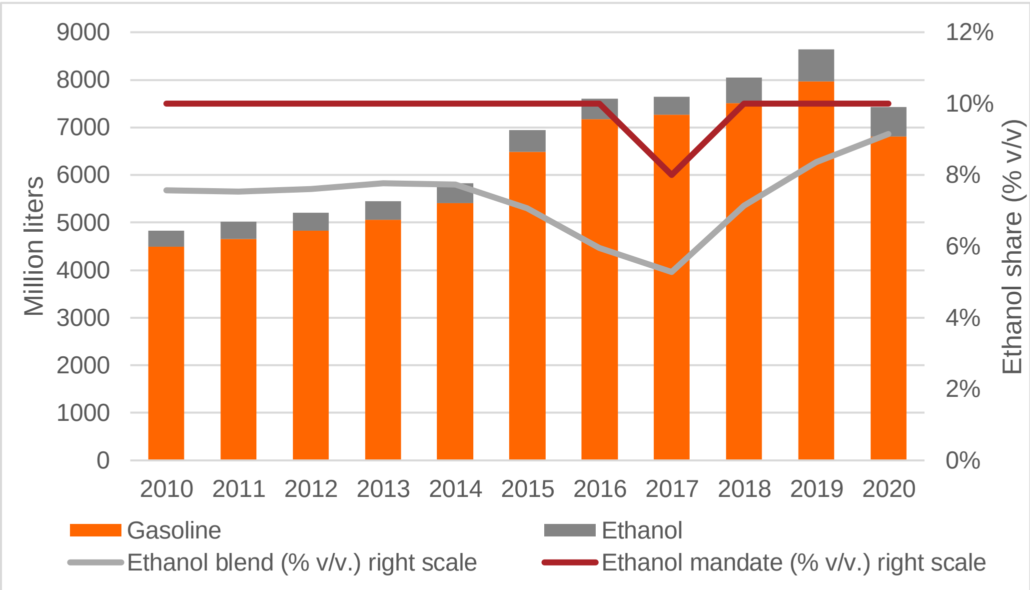


Source: Unit of Mining and Energy Planning

Figure 88 shows the volume of ethanol blended in gasoline since 2012. It can be observed that the ethanol volume blended in gasoline has complied with the ethanol blend mandate in Colombia.

Through the years, the mandate has progressively been implemented in a larger number of cities and regions. Today E10 is the predominate grade in the whole country except in the provinces bordering Venezuela, where E0 is smuggled and distributed. In 2017, the mandate decreased to E8 for some months due to a decrease of available sugarcane. Ethanol blending in Colombia used to have more to do with the domestic availability of ethanol than with fulfilling the mandate in the past. However, as of 2015, Colombia started to import ethanol from the U.S. and currently 30% of ethanol domestic sales come from imports.

Figure 88: Ethanol blended in gasoline in Colombia, 2012-2020



Source: Mining and Energy Planning Unit, Fedebiocombustibles, SGS INSPIRE Compilation

Colombia uses 100% sugarcane as feedstock for the production of ethanol. There are seven ethanol plants in Colombia, with a total production capacity of 2 million liters per day. The figure below depicts ethanol production plants in Colombia and their production capacity.

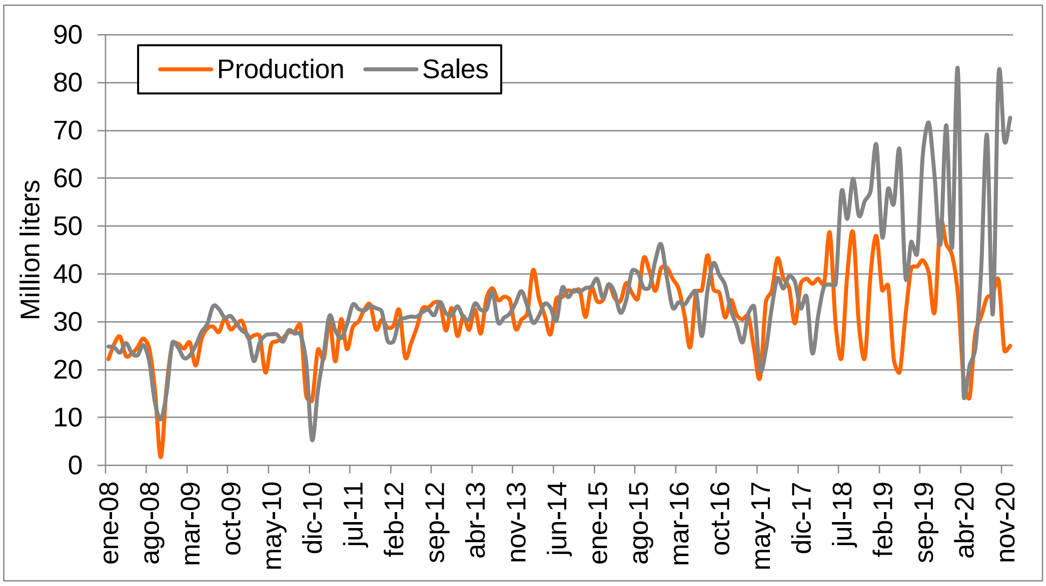
Figure 89: Ethanol plants in Colombia, 2021

Plant	Ethanol (l/day)
Incauca, Miranda (Cauca)	350,000
Ingenio Riopaila Castilla, La Paila (Valle del Cauca)	400,000
Ingenio Risaralda, La Virginia (Risaralda)	100,000
Bioenergy, Puerto López (Meta)	500,000
Ingenio Providencia, Palmira (Valle del Cauca	300,000
Ingenio Mayagüez, Candelaria (Valle del Cauca)	250,000
Manuelita, Palmira (Valle del Cauca)	250,000

Source: Fedebiocombustibles, 2021

Colombia has still potential to increase the area for sugarcane plantations. The country has also potential to increase the yield of sugarcane planted per hectare. From 2008 to 2017, the sugarcane production increased 22% in Colombia, according to Fedebiocombustibles.

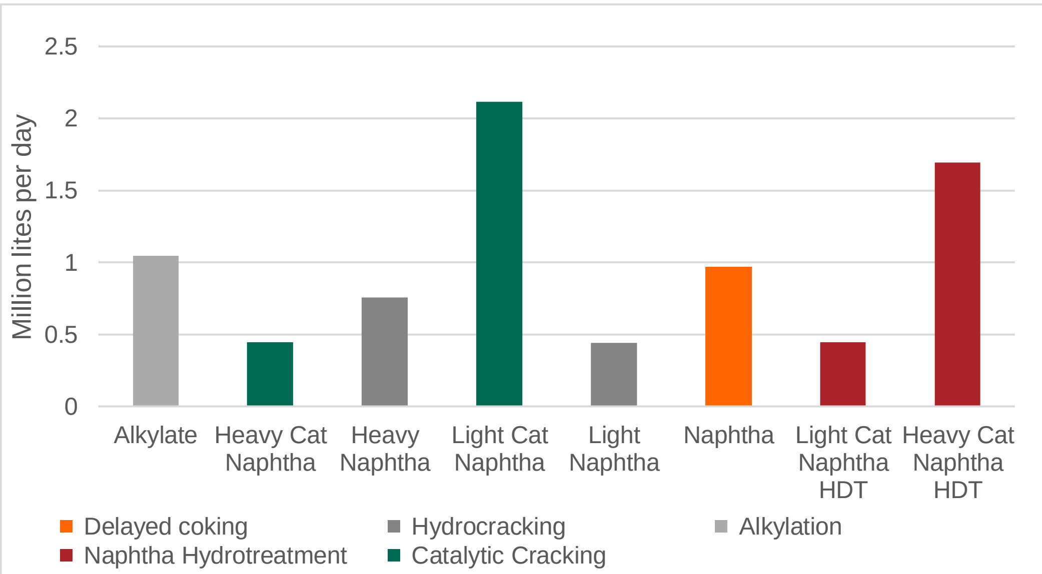
Figure 90: Ethanol production and sales in Colombia, 2010-2020



Source: Fedebiocombustibles, ANH, 2021

The refinery of Cartagena is by far the largest refinery of Colombia. The gasoline blending components produced by the refinery are depicted in the figure below. The largest amount of gasoline components is light and heavy catalytic (cat) naphtha, manufactured both through catalytic cracking and hydrotreatment. Alkylates are also produced.

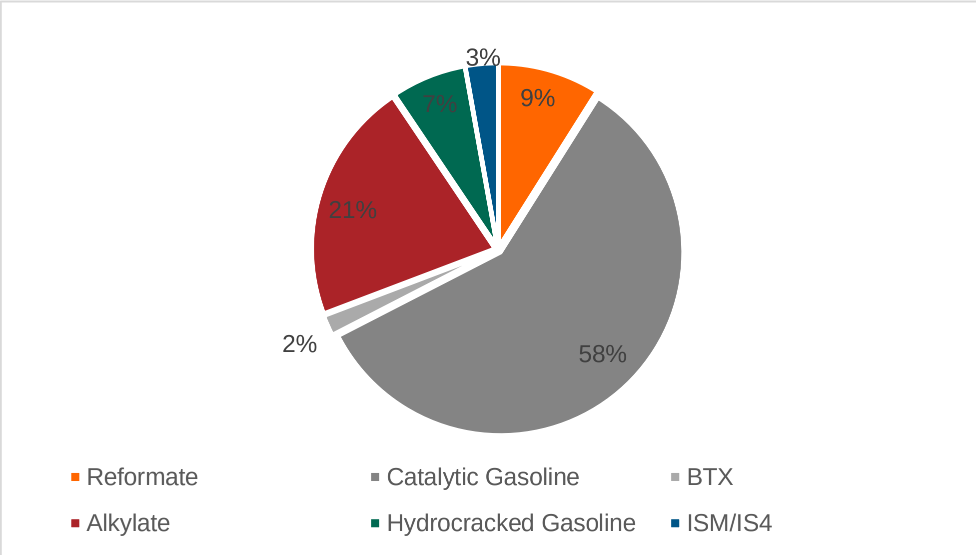
Figure 91: Sub-products obtained to produce gasoline in the Refinery of Cartagena, Colombia



Source: Refinery of Cartagena, Colombia, 2019

The average content of gasoline components used to produce gasoline in Colombia, considering refinery by-products, is the following:

Figure 92: Processed products in the Colombian refineries, 2020



Source: HCX with Wood Mackenzie PennEnergy Research and Oil and Gas Journal data

ECUADOR

REGULATIONS

Gasoline

Current gasoline specifications are defined in standard NTE INEN 935:2020 from February 2020. These specifications update specification NTE INEN 935:2016, published in February 2016. Resolution Nº MPCEIP-SC-2020-0010-R from January 9, 2020, enforces the standard, making it obligatory in the country.

Gasoline specifications are classified in five types according to octane number. This is two more grades as compared with the 2016 specifications.

Figure 93: Past and present gasoline grades according to octane

NTE INEN 935:2016	NTE INEN 935:2020
	RON 85
RON 87	RON 87
	RON 89
RON 92	RON 92
RON 93	RON 93

Source: Ecuadorian specifications

Gasoline grade RON 85 was already in the market, but there were no official specifications for it. RON 89 was introduced as an interim step in increasing the octane of the regular gasoline in the future.

RON 85, 87, 89 and 92 gasoline have sulfur content of 650 mg/kg and RON 93 gasoline has sulfur content of 300 mg/kg.

There was an attempt to reduce sulfur in gasoline to 150 mg/kg with the amendment of standard NTE INEN 935:2016. This was finally not approved, and new version of gasoline standard - NTE INEN 935:2020 - was published in 2020 without the reduction of sulfur.

Ethanol blending is allowed up to 10% v/v, an additional change from the 2016 specifications, when ethanol was not included. For gasoline containing ethanol, certain parameters have different limits.

Figure 94: Differences in specific parameters in gasoline based on ethanol content

Parameter, unit	Gasoline without EtOH	Gasoline with EtOH
Vapor-liquid ratio temperature, ºC	56	53
Vapor pressure, kPa	60/62	67
Oxygen content, wt%	Report	3.7

Source: NTE INEN 935:2020

In September 2020, the government issued Executive Decree 1158, mandating the update of the specifications to Euro 5 level within 120 days after the publication of the Decree. The Decree allowed for supply of fuels compliant with old specification until the 120th day following the official publication of a new standard.

The Decree 1158 was published on October 15, 2020, which means that the new specifications should have been enacted at the latest on January 15, 2021; however, INEN has not yet published the updated standards.

Ethanol

Ethanol (E100) is not used as a neat fuel, but it can be blended with gasoline up to 10% v/v. Standard NTE INEN 2 478:2009 describes requirements for anhydrous ethanol.

Ethanol blending in gasoline in Ecuador began in January 2010 in several fuel stations in Guayaquil, a city at the coast of Ecuador. This pilot project, called ECOPAIS, aimed to introduce E5 gasoline in several cities of Ecuador. Under ECOPAIS project gasoline was a mixture of Extra gasoline (RON 87) and ethanol. Until 2014, “ECOPAIS gasoline” was extended to other cities in the region of Guayas, such as Durán, Milagro and Yaguachi.

Executive Decree Nº 1303 from 2012 was the first piece of legislation promoting the production of biofuels to help the agricultural sector. It allowed the blending of ethanol in gasoline and biodiesel in diesel, but it did not specify a concrete volume of ethanol to be blended.

In 2015, Decree 675 allowed for up to a 10% v/v ethanol blend in the ECOPAIS gasoline. The distribution and commercialization of the ECOPAIS gasoline was planned to be applied progressively throughout the Ecuadorian territory, based on the supply of domestically produced anhydrous ethanol. The ECOPAIS gasoline will progressively replace the whole demand for gasoline marketed as "Extra", with RON 87-85. Currently, 52% of fuel stations in Ecuador sell ECOPAIS gasoline, a total of 529 stations.

CURRENT FUEL QUALITY STANDARDS AND OBJECTIVES

Specifications of gasoline in Ecuador differ from the European specifications enabling Euro 6 emission standards, currently in force in the EU. Ecuador has Euro 2 enabling fuel standards, but Euro 3 vehicle emissions standards for gasoline (Euro I for diesel).

COMPARISON AGAINST STANDARDS

Figure 95 presents the comparison of Ecuadorian and EU specifications, and actual quality of winter gasoline sampled by SGS in selected stations in 2019-2020. The differences between Ecuadorian and EU specifications are mostly related to octane and sulfur. RON and MON are lower than in EU gasoline. Sulfur content is much higher than in the EU gasoline.

Actual quality shown in the table is the average values of 8 samples obtained in Guayaquil and Quito, 5 samples of low regular RON 87 and 3 samples of regular RON 92 gasoline.

Figure 95: Comparison between Ecuadorian and EU specifications and actual quality data

<table>
<tr><th></th><th colspan="5">Ecuador</th><th colspan="2">Ecuador actual gasoline Winter quality 2019/2020 Average</th><th colspan="4">EU</th></tr>
<tr><td>Implementation Date</td><td colspan="5">2020</td><td colspan="2">N/A</td><td colspan="4">2017</td></tr>
<tr><td>Selected Grade</td><td>RON 85</td><td>RON 87</td><td>RON 89</td><td>RON 92</td><td>RON 93</td><td>Low regular 87</td><td>Regular 92</td><td>RON 95 E5</td><td>RON 95 E10</td><td>RON 98 E5</td><td>RON 98 E10</td></tr>
<tr><td>Name</td><td colspan="5">NTE INEN 935:2020</td><td colspan="2">Average values</td><td colspan="4">EN 228:2012 + A1:2017 (Euro 6 enabling)</td></tr>
<tr><td>Benzene Content</td><td colspan="3">< 1 %v/v</td><td>< 2 %v/v</td><td>< 1.3 %v/v</td><td>0.6% v/v</td><td>0.84% v/v</td><td colspan="4">< 1 %v/v</td></tr>
<tr><td>Aromatics</td><td colspan="2">< 30 %v/v</td><td colspan="3">< 35 %v/v</td><td>24.6% v/v</td><td>31.5% v/v</td><td colspan="4">< 35 %v/v</td></tr>
<tr><td>Olefins</td><td colspan="2">< 18 %v/v</td><td colspan="3">< 25 %v/v</td><td>10.8% v/v</td><td>15.4% v/v</td><td colspan="4">< 18 %v/v</td></tr>
<tr><td>Lead Content</td><td colspan="5">< 0 mg/l</td><td colspan="2">< 2.5 mg/l</td><td colspan="4">< 5 mg/l</td></tr>
</table>

Manganese	0 mg/l					< 0.1 mg/l		< 2.0 mg/l			
RON	85	87	89	92	93	85.6	93.2	> 95	> 95	> 98	> 98
Sulfur Content	650 mg/kg				< 300 mg/kg	284 mg/kg		< 10 mg/kg			
Oxygen Content	< 3.7 %m/m (for gasoline with ethanol)					-		< 2.7 %m/m	< 3.7 %m/m	< 2.7 %m/m	< 3.7 %m/m
Ethanol (EtOH)	< 10 %v/v					0.25% v/v		< 5 %v/v	< 10 %v/v	< 5 %v/v	< 10 %v/v
RVP 37.8°C (Summer)	< 60 kPa	< 67 kPa	< 60 kPa	< 60 kPa	< 62 kPa	50.5 kPa		<> 60 - 70 kPa *Depends on the country, RVP is regulated in the EU Fuel Quality Directive			
Ethers 5 or more C Atoms	-					0% v/v		Based on oxygen content	< 22 %v/v	Based on oxygen content	< 22 %v/v

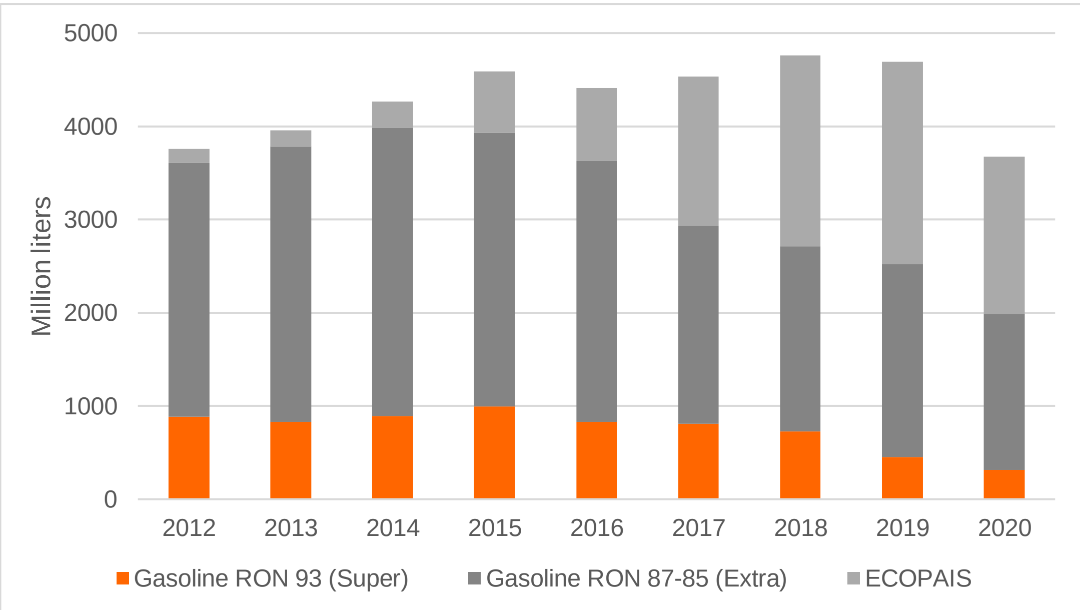
*In orange the values that would not comply with EU specifications and in blue the values that do not comply with Ecuadorian specifications.

Source: Ecuadorian and EU specifications, SGS Worldwide Fuel Survey, 2021

BLENDSTOCK ANALYSIS

Ecuador produces two grades of gasoline, RON 87 (in gasoline extra and ECOPAÍS) and RON 93, as shown in Figure 96. Gasoline production has been decreasing over the years.

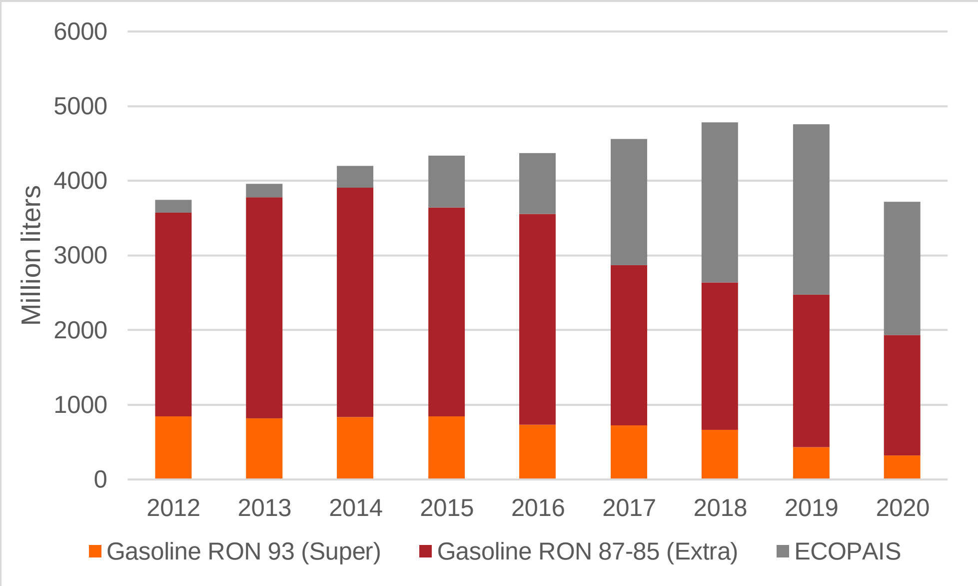
Figure 96: Gasoline production in Ecuador



Source: Petroecuador, 2021

Ecuador produces 96 million liters of ethanol per year. The whole production is used to be blended into gasoline extra to produce gasoline ECOPAIS. The demand for gasoline ECOPAIS has been increasing significantly over the past years, as shown in Figure 97.

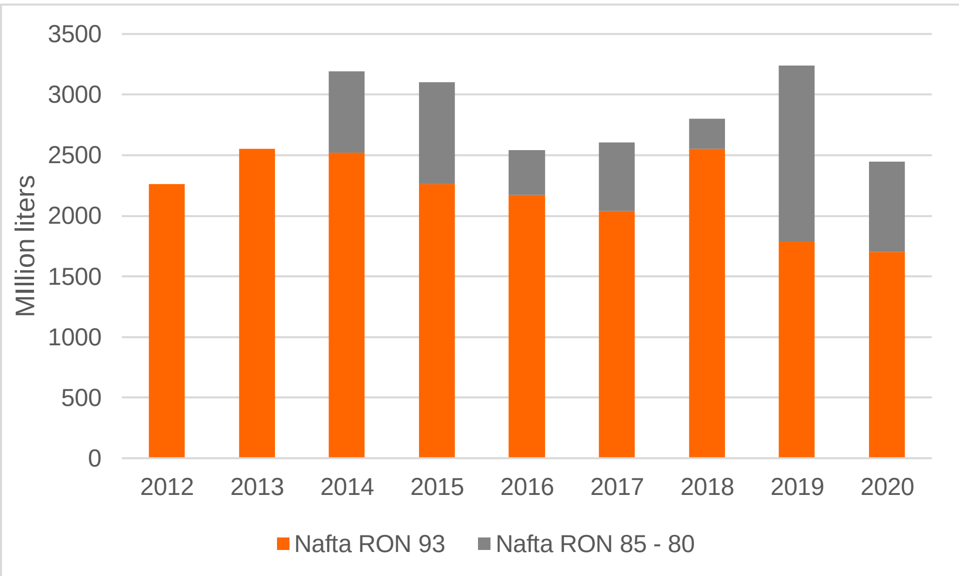
Figure 97: Gasoline demand in Ecuador per ethanol grade, 2012-2020



Source: Petroecuador

Ecuador does not import gasoline, according to Petroecuador, but imports naphtha RON 85-80 and RON 93. However, according to SGS SOL, gasoline imports were approximately 300 million liters, which could have been re-exported to other countries. Most gasoline imported did not have a grade specified, and a small quantity was gasoline RON 93. Furthermore, as can be observed, private companies have started importing gasoline in contrast to the past where only state-owned Petroecuador was allowed to import oil products, although most gasoline imported arrived at the Petropenínsula Terminal. According to United Nations Comtrade, gasoline comes from United States, Sweden, and China.

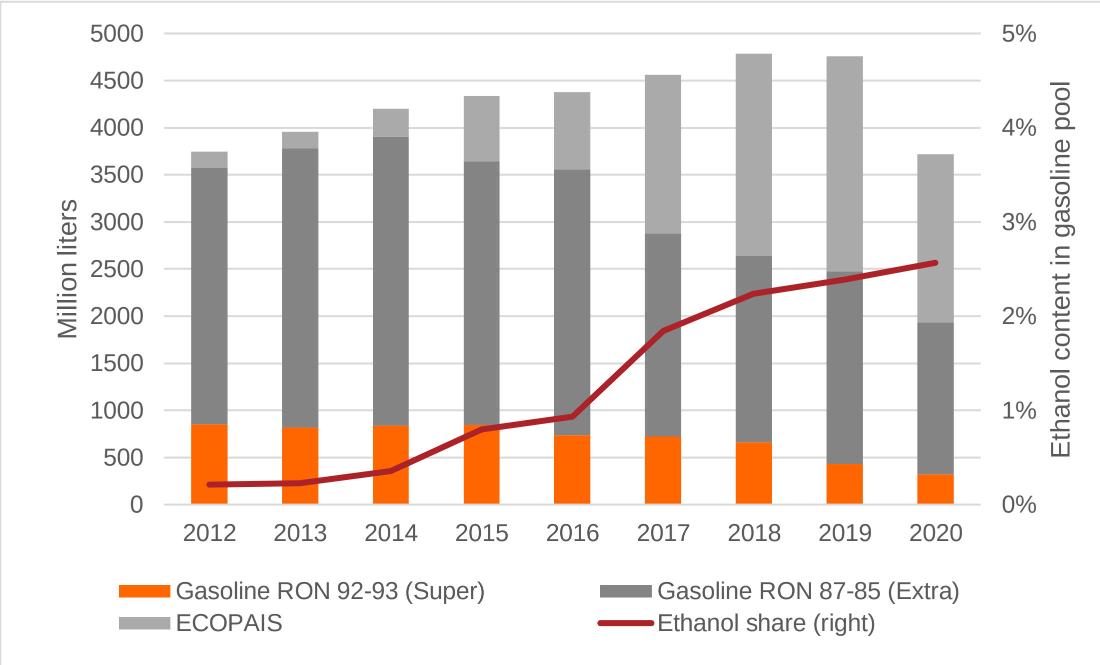
Figure 98: Naphthas imports to Ecuador, 2012-2020



Source: Petroecuador, 2021

Figure 99 shows the volume of ethanol blended in the total gasoline pool since 2012, even though only one gasoline grade contains ethanol in Ecuador, i.e., ECOPAIS. Provided that approximately 5% v/v has been blended in ECOPAIS gasoline since 2010 (although 10% v/v is allowed) it can be observed that the ethanol volume blended in gasoline has increased over the years, namely because of the increase of ECOPAIS gasoline consumption over the years thanks to the beneficial pricing.

Figure 99: Ethanol blended in gasoline in Ecuador, 2012-2020



Source: Petroecuador, SGS INSPIRE Compilation

There is no specific ethanol mandate in Ecuador, only the permission of blending it into gasoline. The distribution and commercialization of gasoline with ethanol is based on the supply of domestically produced anhydrous ethanol.

The three companies that provide anhydrous ethanol to Petroecuador are Producargo S.A., Codana S.A. and Soderal S.A. They provide approximately 96 million liters per year.

The Esmeraldas refinery, the largest of the country, has the following processing units to produce gasoline, according to Petroecuador:

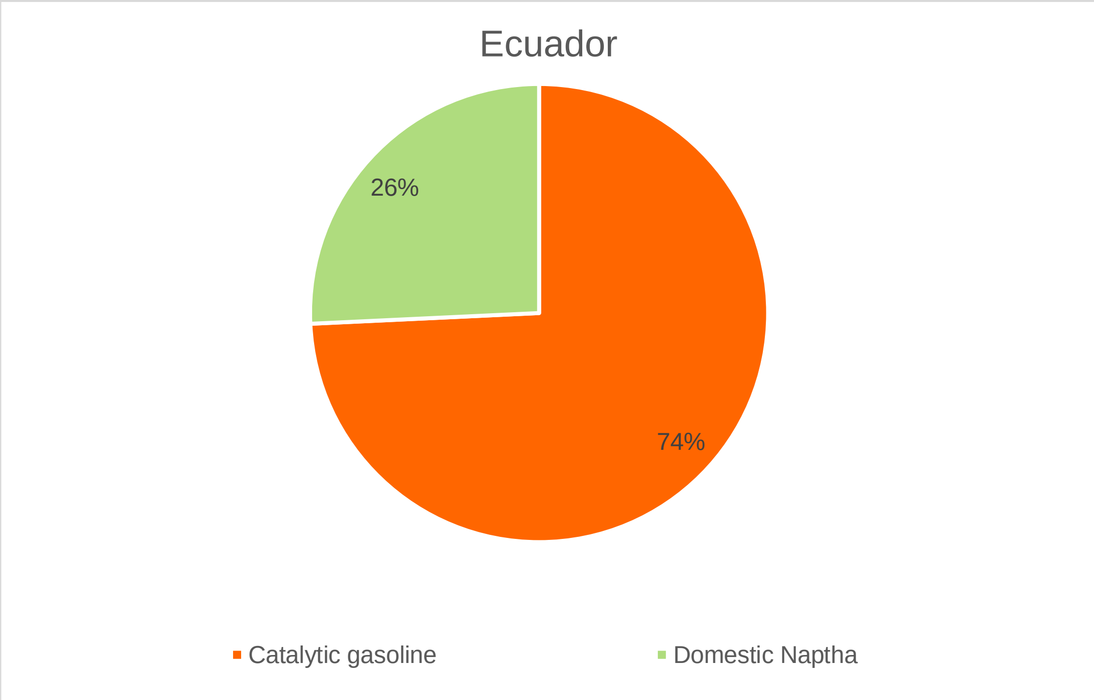
Figure 100: Operation capacity of the Esmeraldas Refinery, Ecuador

Unit	Capacity	Load (barrels per day)
Hydrotreatment	67%	8,735
Catalytic Reforming	85%	8,485
Hydrodesulfurization	95%	23,235

Source: Petroecuador

Therefore, the blendstocks used to produce gasoline in Ecuador are catalytic gasoline (high octane naphtha) and domestic naphtha (low octane naphtha).

Figure 101: Gasoline blending components produced in Ecuador



Source: HCX with Wood Mackenzie PennEnergy Research and Oil and Gas Journal data

MEXICO

REGULATIONS

Gasoline

On August 26, 2016, the Energy Regulatory Commission (Comisión Reguladora de Energía, CRE) published the official Mexican Standard NOM-016-CRE-2016, titled “Specifications of the quality of oil products”. It details the specifications of gasoline, diesel, jet fuel, fuel for industrial use, aviation gasoline, fuel oil, and liquified petroleum gas. The standard is applicable in the whole country since October 28, 2016, for the production and distribution of petroleum products, including imports.

There are two grades of gasoline:

- gasoline regular, also called “Magna”, with octane index of between 87 and 91
- gasoline premium, with octane index of minimum 91

The octane index, also called anti knock index, is defined as: (RON+MON)/2.

The use of ethanol is prohibited in the three metropolitan areas of Valley of Mexico, Guadalajara, and Monterrey. In the rest of the country, a maximum of 5.8% v/v ethanol is allowed as oxygenate in gasoline premium and regular, for which corrosion inhibiting additives can be used. The use of methyl tert-butyl ether (MTBE), ethyl tert-butyl ether (ETBE) and tert-amyl methyl ether (TAME) as oxygenates is allowed in gasoline premium and regular, up to a content of maximum 2.7 %m/m oxygen, in the whole country.

In the current standard NOM-016, the maximum sulfur content per specific batch is 80 mg/kg for both gasoline premium and regular, nationally, and the maximum average annual sulfur content is 30 mg/kg.

CURRENT FUEL QUALITY STANDARDS AND OBJECTIVES

Mexico fuel quality standards are more similar to U.S. specifications than to EU specifications. Current heavy-duty diesel vehicles should comply with either US 2004 or Euro IV vehicle emission standards through June 2019 and are required to meet US 2010 or Euro VI as from January 2022. Light-duty emissions standards are a mix of US Tier 1 to 2 and Euro 3 and 4. Specifications are similar to the latest U.S. fuel quality regulations, except for benzene, whose limit is higher in Mexico. Sulfur content in gasoline is higher in the U.S. compared to Euro 6 enabling specifications.

COMPARISON AGAINST STANDARDS

The table below presents the comparison between Mexican specifications, EU specifications and actual quality of winter gasoline from 2020-2021. The differences between Mexican and EU specifications are mostly related to octane, sulfur, and benzene. It is worth mentioning that the aromatics limit in Mexican specifications is lower than in EU specifications, but olefins are only regulated in large metropolitan regions. RON is lower than average EU gasoline. Sulfur content is a bit higher than in EU gasoline.

Actual quality shown in Figure 102 is the average values of 12 samples: 4 samples of regular unleaded, 2 samples of regular E5.8, 4 samples of premium unleaded and 2 samples of premium E5.8.

Figure 102: Comparison between Mexican and EU specifications and actual quality data

	Mexico Specifications	**Mexican actual gasoline quality Winter 2020-2021 Average**	**EU Specifications**
Implementation Date	2016	2020/2021	2017

Selected Grade	Gasoline Regular	Gasoline Premium	Gasoline Regular	Gasoline Premium	RON 95 E5	RON 95 E10	RON 98 E5	RON 98 E10
Name	NOM-016-CRE-2016		Average values		EN 228:2012 + A1:2017 (Euro 6 enabling)			
Benzene Content	< 2 %v/v (< 1 %v/v in metropolitan regions of Mexico City, Guadalajara, Monterrey)		0.56% v/v		< 1 %v/v			
Aromatics	Report < 32 %v/v in Guadalajara and Monterrey < 25 %v/v in Mexico City	22.6% v/v	22.6% v/v		< 35 %v/v			
Olefins	Report < 10 %v/v in Mexico City < 11.9 %v/v in Guadalajara and Monterrey	< 2.5 mg/l	8.2% v/v		< 18 %v/v			
Lead Content	-		2.5 mg/l		0.005 g/l			
Manganese	0 mg/l		< 0.1 mg/l		< 2.0 mg/l			
RON		94	91.9	96.2	> 95	> 95	> 98	> 98
MON	82		83.5	86.4	> 85	> 85	> 88	> 88
Sulfur Content	< 80 mg/kg		18.2 mg/kg	10.7 mg/kg	< 10 mg/kg			
Oxygen Content	< 3.7 %m/m	< 2.7 %m/m	-	-	< 2.7 %m/m	< 3.7 %m/m	< 2.7 %m/m	< 3.7 %m/m
Ethanol (EtOH)	> 5.8 %v/v (not allowed in metropolitan regions of Mexico City, Guadalajara, Monterrey)		0% v/v (no ethanol found in the ethanol blends)		< 5 %v/v	< 10 %v/v	< 5 %v/v	< 10 %v/v
RVP 37.8°C (Summer)	< 69 kPa North < 62 kPa Center, South, Pacific, Monterrey				< 62 kPa	<> 60 - 70 kPa *Depends on the country, RVP is regulated in the EU Fuel Quality Directive		
RVP 37.8°C (Winter)	< 79 kPa North, Center, South, Pacific, Monterrey		65.3 kPa					
RVP 37.8°C (Transition)	< 54 kPa Mexico City and Guadalajara		52.4 kPa					
Ethers 5 or more C Atoms	-				Based on oxygen content	< 22 %v/v	Based on oxygen content	< 22 %v/v

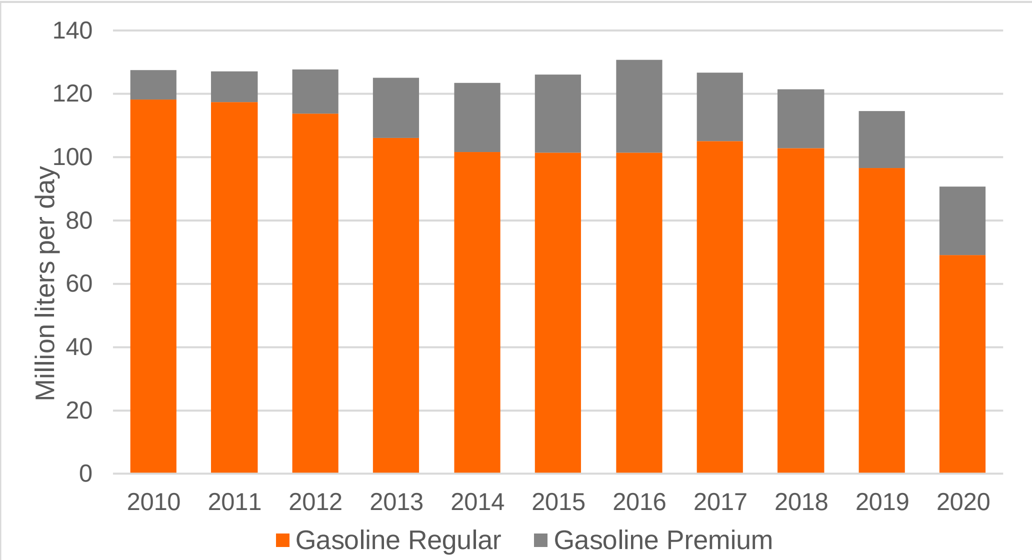
*In orange the values that would not comply with EU specifications and in blue the values that do not comply with Mexican specifications.

Source: Mexican and EU specifications, SGS Worldwide Fuel Survey, 2021

BLENDSTOCK ANALYSIS

The consumption of gasoline per grade is shown in Figure 103. Gasoline regular is the main grade in the market, amounting to 70% of the gasoline consumed in 2020. Due to the COVID-19 pandemic, consumption of total gasoline decreased 20% in 2020 compared to 2019.

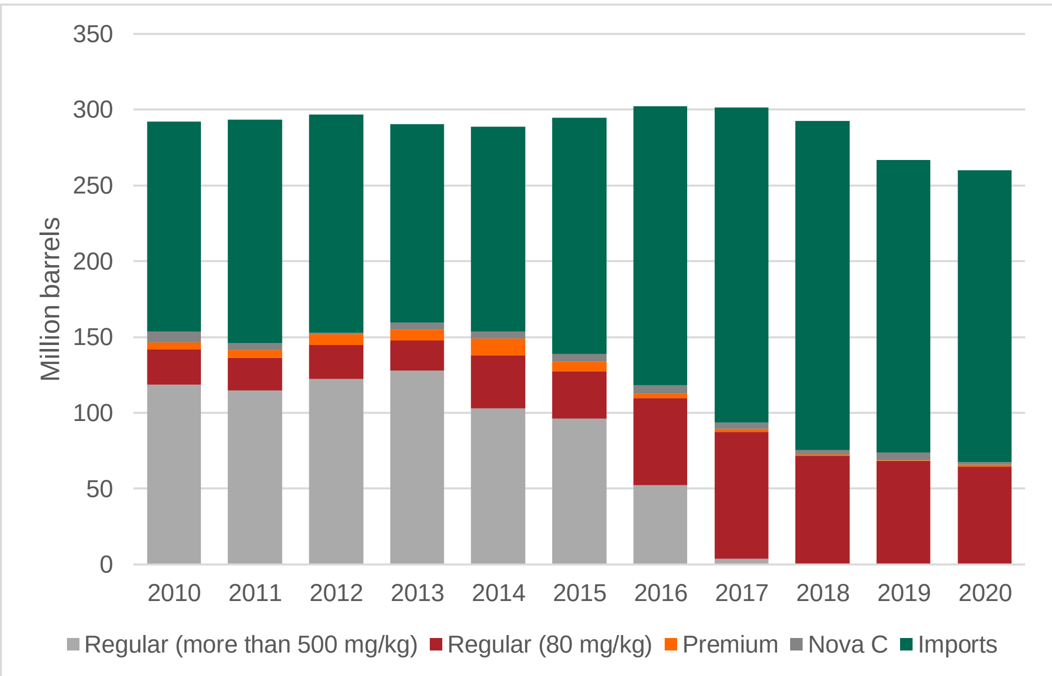
Figure 103: Gasoline consumption in Mexico



Source: SENER 2021

Figure 104 shows the production of gasoline by Pemex, and imports, since 2010. Production of regular gasoline with 80 mg/kg sulfur content started in 2009 and increased to gradually replace high-sulfur gasoline in 2018. The production of regular gasoline decreased from around 130 million liters in 2010 to 90 million liters in 2020. Premium gasoline production in Mexico is currently insignificant. In the refinery of Minatitlan there is some production of gasoline Nova C, a low octane grade which is no longer suitable for consumption.

Figure 104: Gasoline production and imports in Mexico



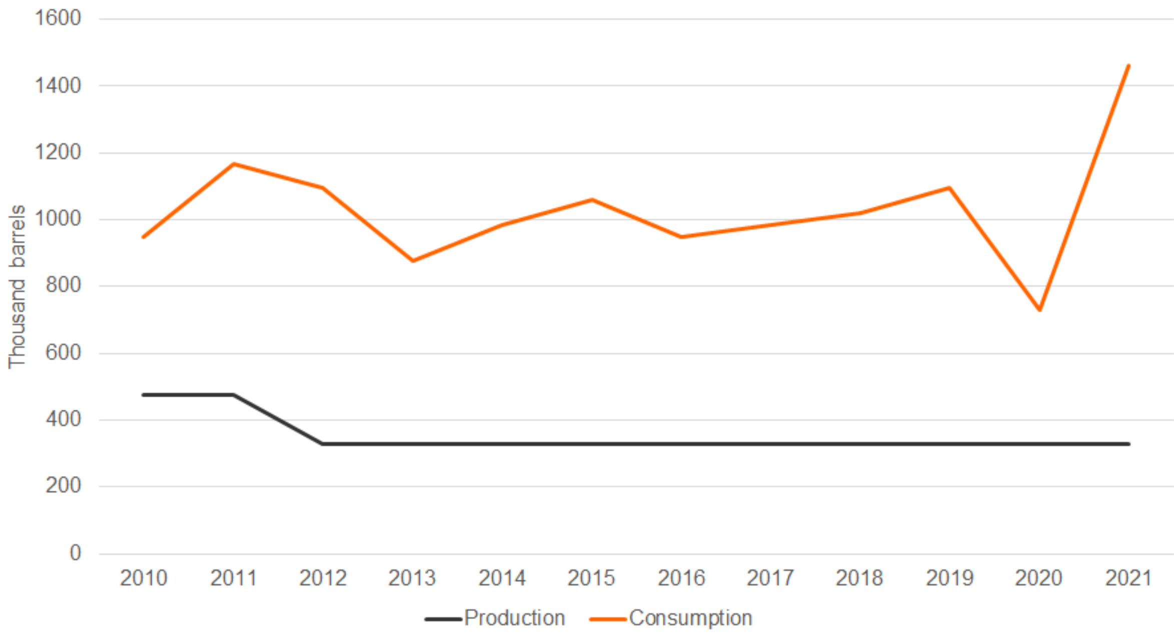
* mg/kg refers to sulfur. The Secretary of Energy (SENER) does not specify grade in the total gasoline imports data provided. Nova C is not used any longer in Mexico.

Source: SENER, 2021

Imported gasoline mainly comes from the United States. The other main countries of origin for the past year are the Netherlands, Singapore, and Spain. Since the Energy Reform in 2013, several private companies import gasoline to Mexico, although most of the gasoline is still being imported by Pemex.

The production and consumption of fuel ethanol is shown in Figure 105. Ethanol consumption increased in 2021, but demand is not yet significant. Most of the imported fuel ethanol comes from the U.S. With the 2020 tribunal injunction raising the ethanol blending limit from 5.8% v/v. to 10% v/v., it is expected that the production, consumption and imports of fuel ethanol will sharply rise in the short-term, since ethanol represents a more economic oxygenate alternative than MTBE or other compounds used today in Mexico.

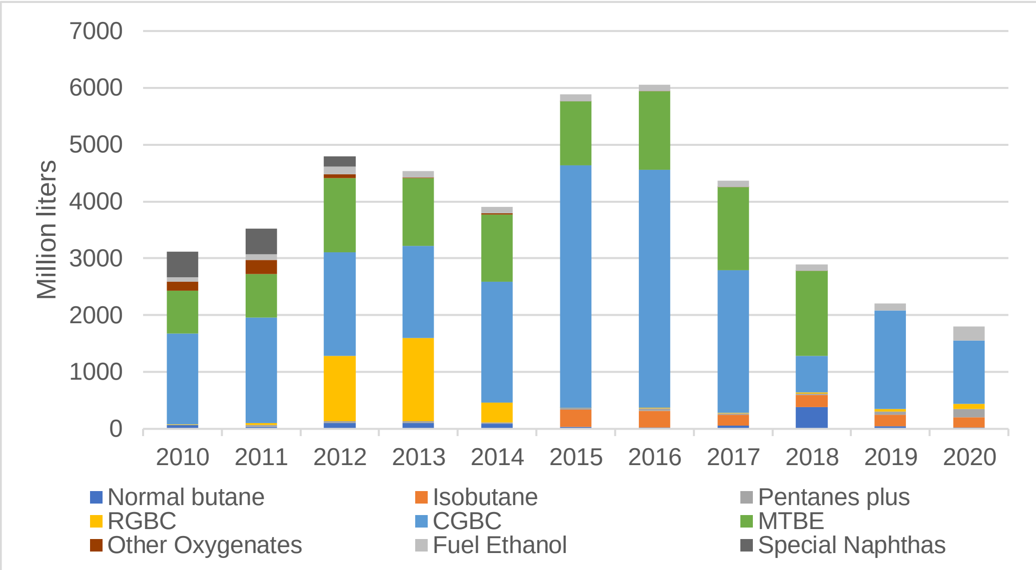
Figure 105: Production and consumption of fuel ethanol in Mexico



Source: Energy Information Administration, 2021

Mexico imports significant amounts of blending components to produce gasoline from the U.S. The country used to import reformulated gasoline blending components (RGBC), but currently conventional gasoline blending components (CGBC) are imported. It is also important to notice that no MTBE has been imported from the U.S. in 2019 and 2020 (or no information about it is recorded).

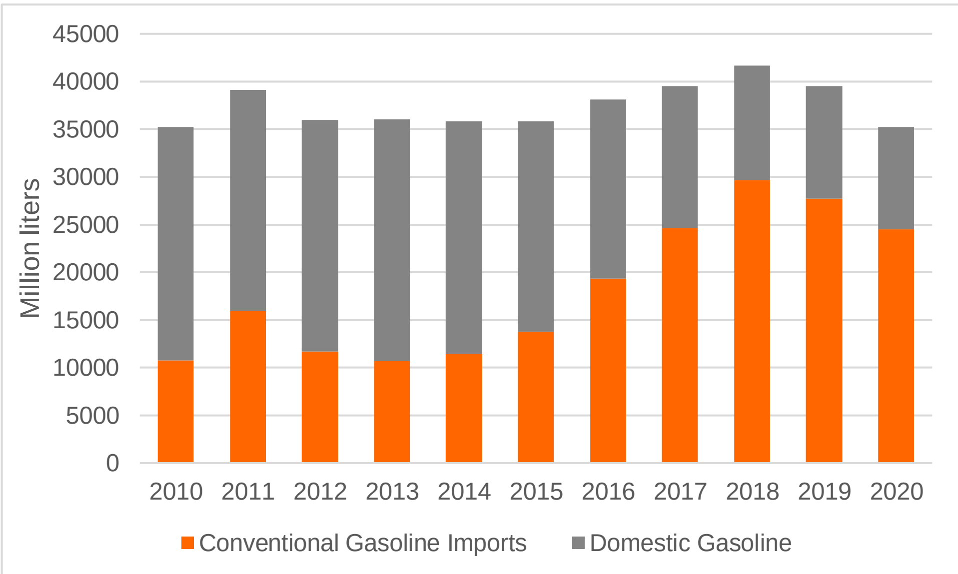
Figure 106: U.S. Exports of blending components to Mexico



Source: U.S. EIA, 2021

Since 2012 Mexico has been importing finished gasoline from the U.S., all of it is conventional grade. Imports have been increasing until 2018 and started decline in 2019 along overall decline in the gasoline consumption in the country.

Figure 107: Gasoline consumption in Mexico divided by imports and domestic production



Source: SENER, EIA

PEMEX has a capacity of processing gasoline in three main units, as shown below.

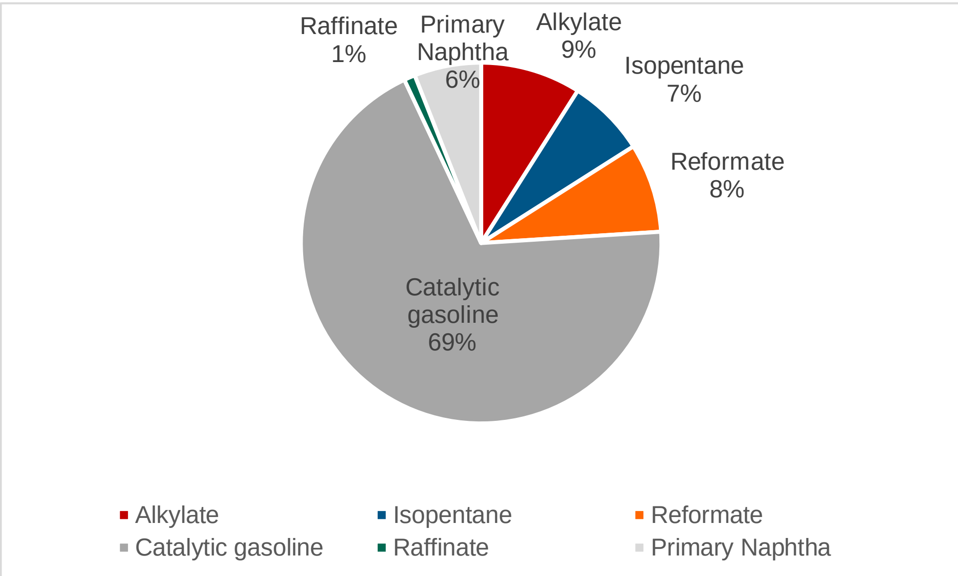
Figure 108: Capacity of processing of refineries in Mexico (thousand barrels per day)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Naphtha reformate	279	279	279	279	279	279	279	279	279	279
Hydrodesulfurization	1010	1067	1067	1067	1067	1100	1230	1230	1230	1230
Alkylates and Isomerates	128	128	142	155	155	154	155	154	154	154

Source: PEMEX, 2021

Thus, considering the processing units of PEMEX, U.S. gasoline blending components imported and U.S. gasoline imports, the mostly likely average gasoline blending components of Mexican gasoline are the following:

Figure 109: Share of gasoline blending components in Mexico



Source: PEMEX, EIA, SGS INSPIRE Compilation

PERU

REGULATIONS

Gasoline

Current gasoline specifications are defined in the standard **NTP 321.102** from January 31, 2017, which supersedes **NTP 321.102** from 2002. **Directorial Resolution Nº 001-2017-INACAL/DN** from January 31, 2017, implemented this standard into legislation.

The 2017 standard implemented two gasoline grades depending on octane:

- Gasoline regular RON 91
- Gasoline premium RON 97

The maximum sulfur content requested for all grades is 50 mg/kg and the RVP value is 10 psi (69 kPa).

Expired gasoline specification NTP 321.102 from 2002 included four grades depending on octane:

- Gasoline regular RON 84
- Gasoline super RON 90
- Gasoline premium RON 95
- Gasoline super extra RON 97

The maximum sulfur content requested for all grades was 1,000 mg/kg and the RVP value was 10 psi (69 kPa).

However, Article 2 of Supreme Decree Nº 025-2017-EM, which established measures related to the use of diesel, gasoline and ethanol blends, determined that the sulfur content of high octane gasoline and ethanol blends (RON 95, RON 97 and RON 98) must not be higher than 50 mg/kg as of January 1, 2018. This obligation was enforced on importers. The date of implementation was March 31, 2018, for the other stakeholders, such as suppliers.

Gasoline without ethanol is supplied in Peru only in the provinces of Amazonas, San Martín, Loreto, Ucayali, and Madre de Dios. These provinces are in the Amazonas or close to it and their accessibility is more difficult than the other provinces in the country.

Peru has an ethanol blending mandate of 7.8% v/v. Ministerial Resolution Nº 515/2009 from December 7, 2009, specifies the ethanol blend grades in the country. The grades should have the octane rate established in the resolution before the ethanol blending:

- Ethanol blend RON 84
- Ethanol blend RON 90
- Ethanol blend RON 95
- Ethanol blend RON 97

According to the SGS Worldwide Fuel Survey (WWFS) winter 2019/2020 season, all four grades are in the market. The maximum sulfur content for RON 84 and RON 90 grades in the market is 2,000 mg/kg and the RVP value stands at 11 psi (76 kPa). For RON 95 and RON 97, the maximum sulfur content allowed is 50 mg/kg.

Ethanol

Anhydrous Denatured Ethanol specification NTP 321.126 from 2011, and reviewed in 2017, is the Peruvian standard for fuel ethanol to be blended in gasoline.

Ethanol blending in Peru was initiated with the ethanol blend mandate. The initial schedule was established in 2007 but was modified several times until all regions introduced the mandate at the end of 2011.

The two initial pieces of legislation related to biofuels sought the promotion and regulation of the biofuels market in Peru.

Law 28054 on Biofuels Market Promotion from April 20, 2007, established the legal framework for promoting the use of biofuels in Peru and promoted investment in biofuel production and its distribution. Additionally, Supreme Decree 021-2007-EM Regulation for the Commercialization of Biofuels also from April 2007, established legal requirements for distributing biofuels in Peru, while also established minimum quality standards and procedures for registering biofuel blends with the Ministry of Energy and Mines.

CURRENT FUEL QUALITY STANDARDS AND OBJECTIVES

Peru has two grades on the market: gasoline and ethanol blend. Ethanol blend is equivalent to Euro 1 enabling specifications, while gasoline specifications are similar to Euro 4 enabling specifications. Not all properties are the same as European specifications, this comparison is mostly based on sulfur limits.

Furthermore, vehicle emissions standards in place are Euro 4 for light-duty vehicles and Euro IV for heavy-duty vehicles. Euro 6/VI vehicle emissions standards will be implemented in 2023-2025 depending on the fuel and the vehicle size.

COMPARISON AGAINST STANDARDS

Figure 110 presents the comparison of Peruvian specifications, EU specifications and actual quality of winter gasoline from 2019-2020. The differences between Peruvian and EU specifications are mostly related to octane and sulfur. RON requirements are significantly lower than in the EU specifications. The ethanol blend mandate required in Peru is 7.8% v/v, while in the EU is either 5% v/v or 10% v/v, depending on the country. Allowed sulfur content is much higher in Peru than in the EU specifications, but actual content is only a bit higher than in EU gasoline. Also, some manganese was found in RON 84 in Peru, while it is not used in the EU.

Actual quality shown is the average values of 12 samples: 2 samples of RON 84 E7.8, 4 samples of RON 90 E7.8, 4 samples of RON 95 E7.8 and 2 samples of RON 97 E7.8 collected in Arequipa and Lima.

Figure 110: Comparison between Peruvian and EU specifications and actual quality data

	Peru Specifications				**Peru actual gasoline Winter quality 2019/2020 Average**				**EU Specifications**			
Implementation Date	2009				N/A				2017			
Selected Grade	Ethanol Blend RON 84	Ethanol Blend RON 90	Ethanol Blend RON 95	Ethanol Blend RON 97	Ethanol Blend RON 84	Ethanol Blend RON 90	Ethanol Blend RON 95	Ethanol Blend RON 97	RON 95 E5	RON 95 E10	RON 98 E5	RON 98 E10
Name	Ministerial Resolution N° 515-2009-MEM/DM				Average values				EN 228:2012 + A1:2017 (Euro 6 enabling)			
Benzene Content	< 2 %v/v (gasoline with no ethanol)				0.66% v/v				< 1 %v/v			
Aromatics	< 45 %v/v (gasoline with no ethanol)				28.3% v/v				< 35 %v/v			
Olefins	< 25 %v/v (gasoline with no ethanol)				13.4% v/v				< 18 %v/v			
Lead Content	< 0.013 g/l				< 2.5 mg/l				< 5 mg/l			
Manganese	< 8.3 mg/l (gasoline with no ethanol)				**29 mg/kg**	0	0	0	< 2.0 mg/l			
RON	> 84	> 90	> 95	> 97	**87.9**	**93.2**	97.0	98.8	> 95	> 95	> 98	> 98
MON	-				-				> 85	> 88	> 85	> 88
Sulfur Content	< 2000 mg/kg (< 50 mg/kg gasoline with no ethanol)				**165 mg/kg**	**168 mg/kg**	**12 mg/kg**	10 mg/kg	< 10 mg/kg			

Oxygen Content	< 0.35 %m/m (gasoline with no ethanol)	-	< 2.7 %m/m	< 3.7 %m/m	< 2.7 %m/m	< 3.7 %m/m
Ethanol (EtOH)	< 7.8 %v/v	7.59% v/v	< 5 %v/v	< 10 %v/v	< 5 %v/v	< 10 %v/v
RVP 37.8°C (Summer)	< 76 kPa	66.8 kPa		<> 60 - 70 kPa *depends on the country, RVP is regulated in the EU Fuel Quality Directive		
Ethers 5 or more C Atoms	-	0% v/v	Based on oxygen content	< 22 %v/v	Based on oxygen content	< 22 %v/v

*In orange the values that would not comply with EU specifications and in blue the values that do not comply with Peruvian specifications.

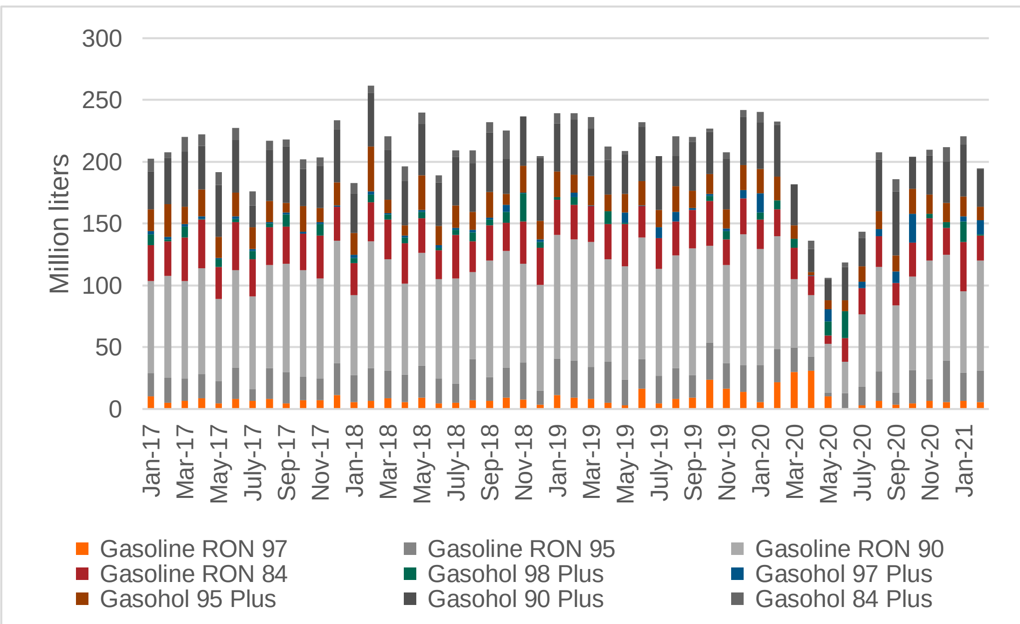
Source: Peruvian and EU specifications, SGS Worldwide Fuel Survey, 2021

BLENDSTOCK ANALYSIS

Peru does not produce all the gasoline demanded by the market. There are five octane grades sold in the market, however, only four of them are included in the specification. Gasoline RON 98 is sold in provinces with a significant population density as a high-quality commodity.

Peru produces mostly gasoline RON 90 and gasoline RON 84, and imports RON 95, RON 97, and RON 98. Domestic refineries do not have significant capacity to produce high octane gasoline, as can be observed in Figure 109. This is the main reason why the government required only gasoline with octane higher than 95 to have 50 mg/kg sulfur. RON 98 grade is an expensive commodity offered by fuel producers as a premium product, and it is only sold in large cities as Lima or Callao. Also, gasoline technical specifications do not cover this grade. Production of total gasoline in Peru is uneven and can vary significantly from month to month. It goes from 170 million to 260 million liters per month.

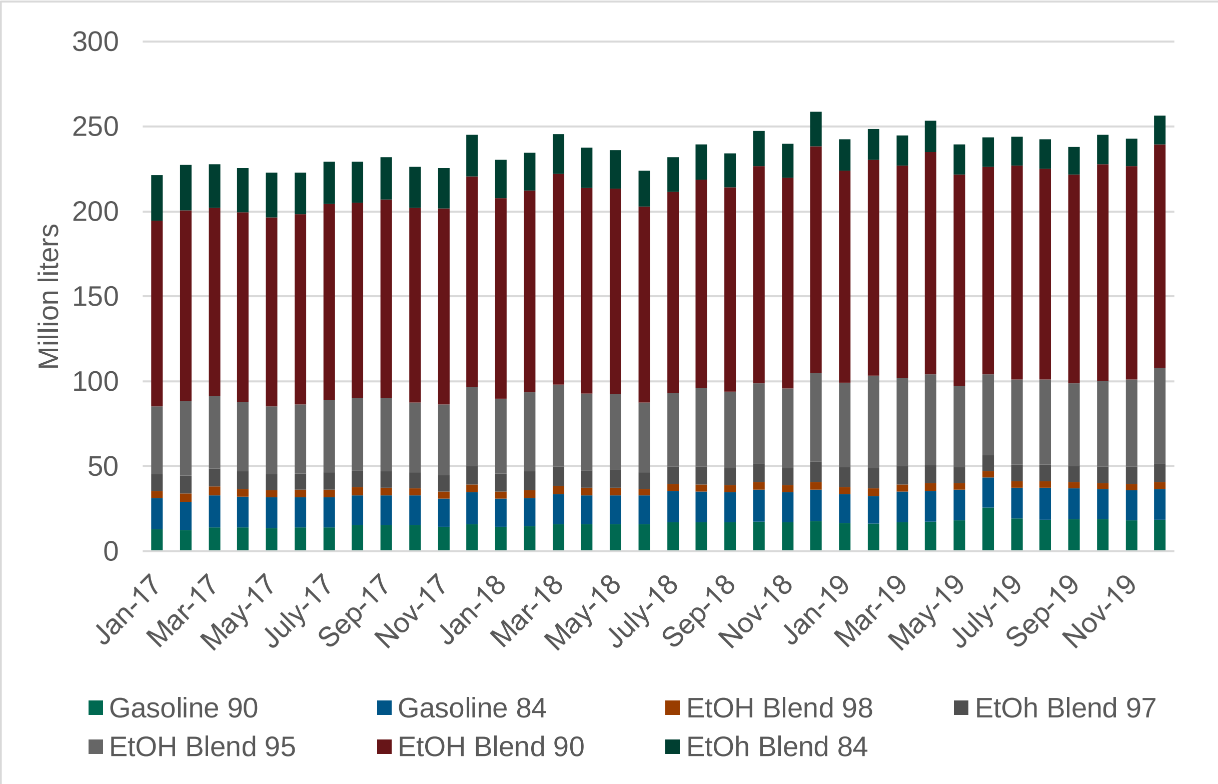
Figure 111: Gasoline and ethanol blend production in Peru per octane grade



Source: Supervisory Agency for Investment in Energy and Mining of Peru (OSINERGMIN), SGS INSPIRE Compilation

Gasoline demand is approximately 10% higher than gasoline supply in Peru. Monthly consumption of gasoline has increased from January 2017, but not significantly.

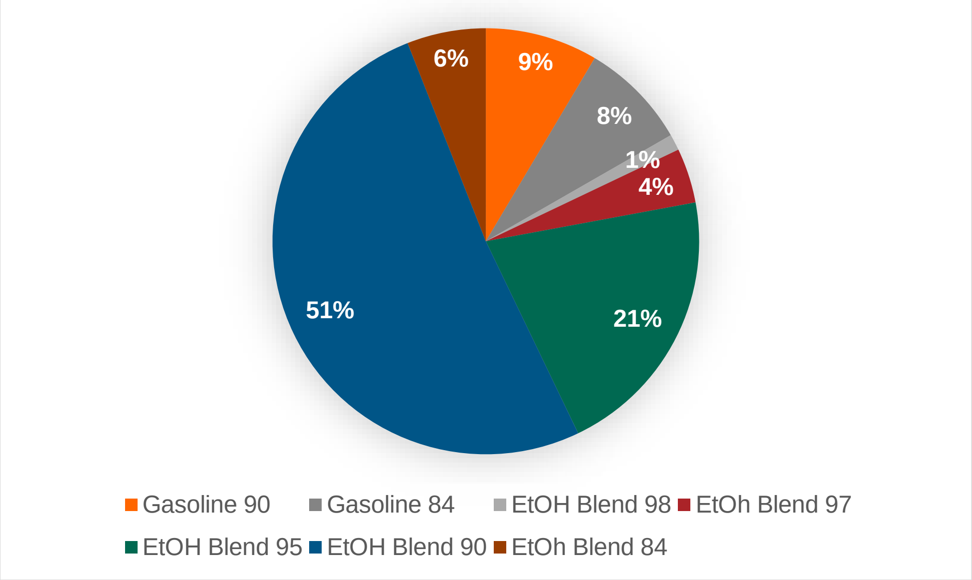
Figure 112: Gasoline demand in Peru per octane grade



Source: Supervisory Agency for Investment in Energy and Mining of Peru (OSINERGMIN), SGS INSPIRE Compilation

Figure 113 illustrates the share of each octane grade in the gasoline market in Peru as of September 2020.

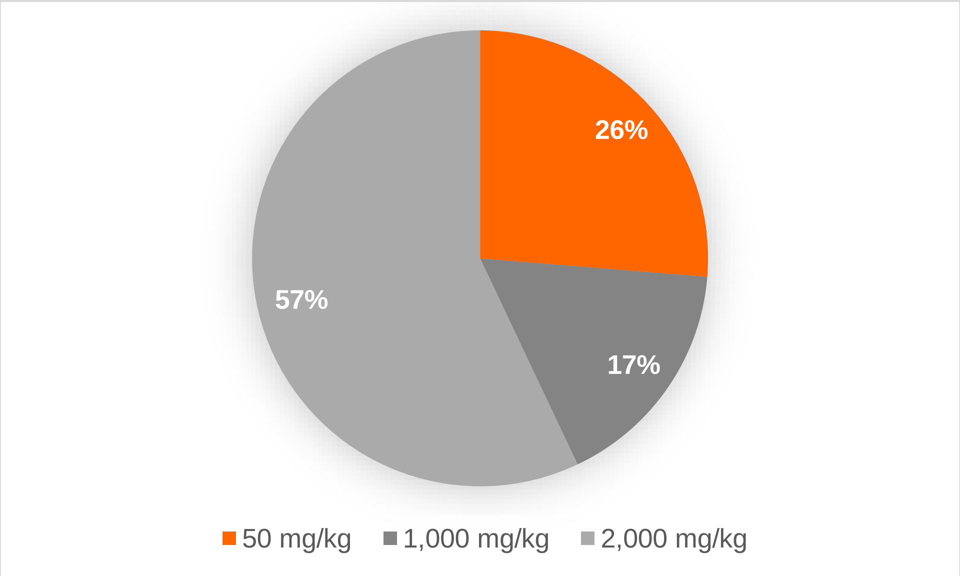
Figure 113: % Share of gasoline per octane grade, September 2020



Source: Supervisory Agency for Investment in Energy and Mining of Peru (OSINERGMIN), SGS INSPIRE Compilation

Figure 114 illustrates the % share of 50 mg/kg sulfur gasoline in the market compared to 1,000 mg/kg gasoline and 2,000 mg/kg ethanol blend gasoline.

Figure 114: % Share of gasoline per sulfur grade in Peru, September 2020



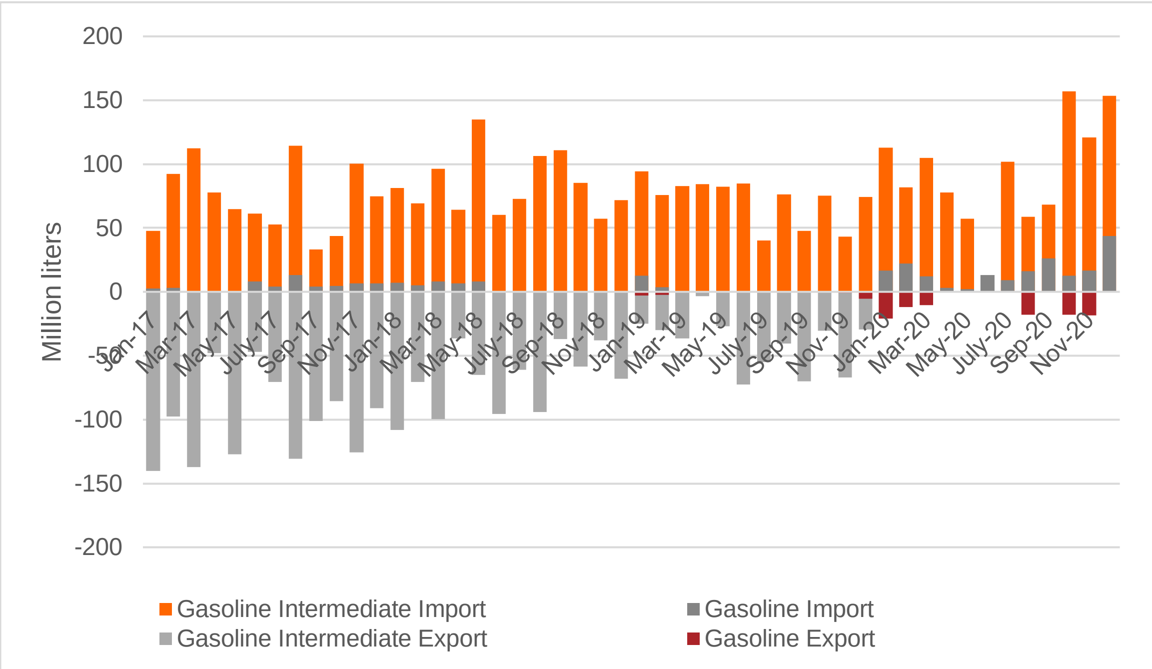
Source: The Supervisory Organism for Energy and Mining Investment, OSINERGMIN, SGS INSPIRE Compilation

Figure 115 demonstrates that imports and exports of finished gasoline are insignificant, while cracked naphtha (gasoline intermediate) is traded in significant volumes; however, their imports and exports have decreased over the 2017-2019 years. More significant decrease in exports coincides with the slight increase in gasoline demand domestically.

Furthermore, SGS SOL data indicate almost 700 million liters of gasoline (with no grade specified) imported by the Talara refinery terminal from Petroperu. Small quantities of other gasoline blendstocks were also imported.

According to United Nations Comtrade, imports came from Brazil, Colombia, Mexico, and Europe in 2019.

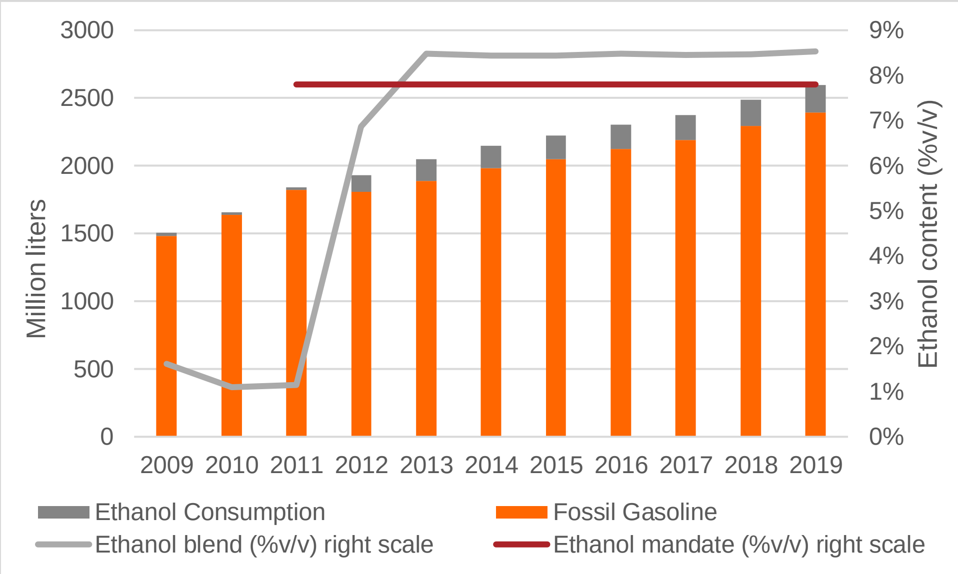
Figure 115: Gasoline imports to Peru, 2009-2020



Source: Supervisory Agency for Investment in Energy and Mining of Peru (OSINERGMIN), SGS INSPIRE Compilation

As can be seen in the figure below, the ethanol mandate was fulfilled in mid-2012 (in the provinces where the mandate was required) and has been stable at 8.5 %v/v since then. The growing pace of demand for E7.8 gasoline has slowed in recent years as taxis and buses increasingly turn to liquefied natural gas (LNG) and liquefied petroleum gas (LPG).

Figure 116: Ethanol blended in gasoline in Peru, 2009-2019



Source: U.S. Department of Agriculture Gain Report Biofuels Annual, SGS INSPIRE Compilation

Supreme Decree 013-2005-EM - Regulation for Biofuels Market Promotion sets the ethanol content in gasoline distributed in Peru at 7.8 %v/v in all provinces except in the Amazonas and neighboring regions. This minimum blend level mandate applies to all gasoline grades.

The initial schedule for the introduction of the ethanol blend in Peru in 2005 was as follows:

Figure 117: Initial Schedule for Ethanol Blend Introduction in Peru

	June 30, 2006	**January 1, 2008**	**January 1, 2020**
Regions	La Libertad, Lambayeque, Ancash, Piura, Barranca and Huaura	Loreto, Ucayali, Amazonas, San Martín y Huánuco	All regions

Source: Supreme Decree 013-2005 EM

Four additional decrees (Supreme Decree Nº 064-2008-EM, Supreme Decree Nº 091-2009-EM, Supreme Decree Nº 061-2010-EM and Supreme Decree Nº 024-2011-EM) were published years later and modified some provisions regulating the biofuel distribution in Peru and established new schedules for biofuel blending minimums in fossil fuels. The last schedule left the Amazonian regions outside of the scope of ethanol blending requirement. The other regions fulfilled the schedule on time.

Gasoline without ethanol is supplied in Peru only in the provinces of Amazonas, San Martín, Loreto, Ucayali and Madre de Dios. These provinces are in the Northeast of the country, in the Amazonas or close to it, and their accessibility is more difficult than the other provinces in the country.

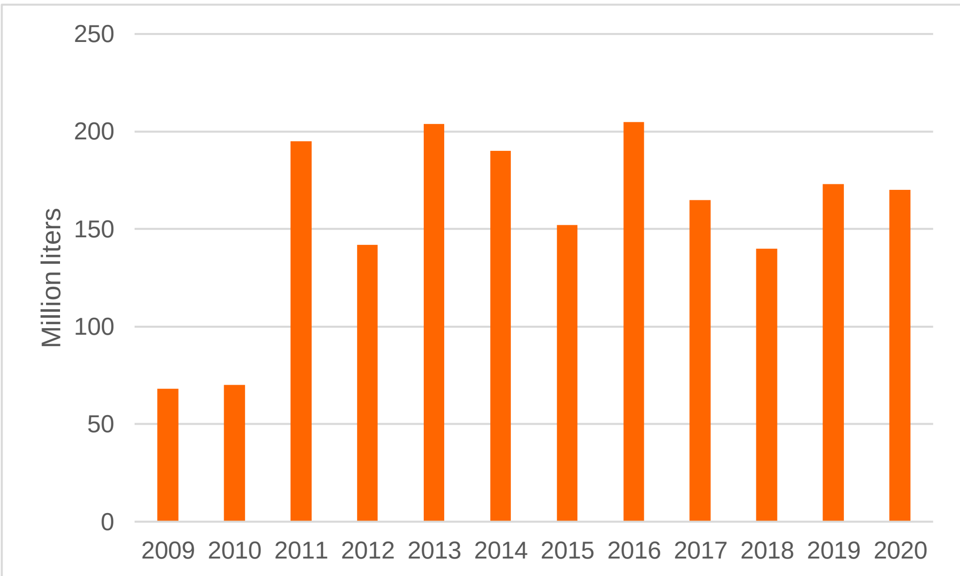
Ethanol blends are supplied in the provinces of Ancash, Apurimac, Arequipa, Ayacucho, Cajamarca, Cusco, Huancavelica, Huanuco, Ica, Junín, La Libertad, Lambayeque, Lima North, Lima South, Moquegua, Pasco, Piura, Puno, Tacna, and Tumbes. All ethanol blend grades on the market contain the same amount of ethanol.

Figure 118: Ethanol blending per region in Peru

Source: SGS INSPIRE Compilation

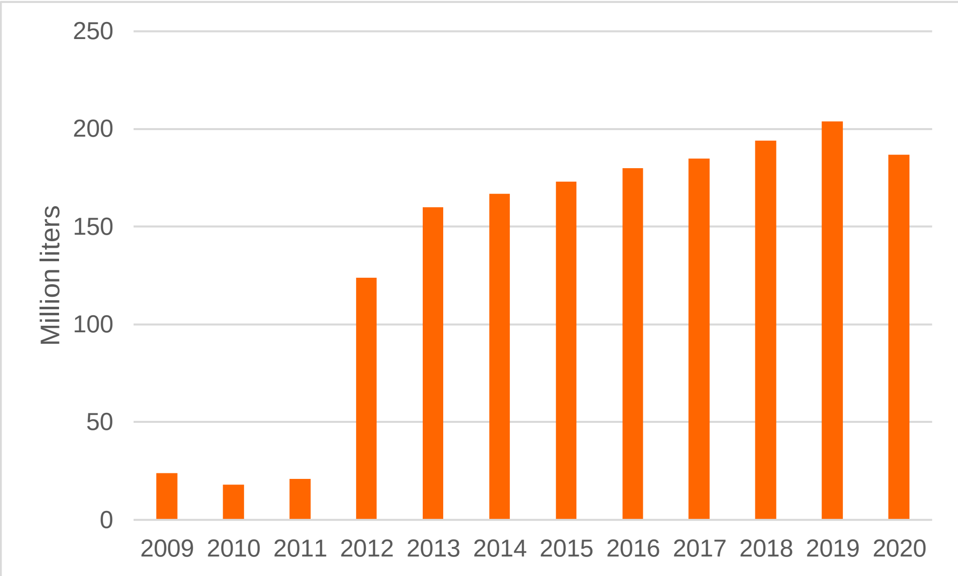
In Peru, there are two ethanol production facilities located in the North part of the country: Aurora and Caña Brava. Peru uses sugarcane as the feedstock for ethanol production. The Aurora facility owned by Coazucar´s is configured to produce sugar or ethanol depending on the economics at a given moment.

Figure 119: Ethanol production in Peru, 2009-2020



Source: U.S. Department of Agriculture Gain Report Biofuels Annual, SGS INSPIRE Compilation

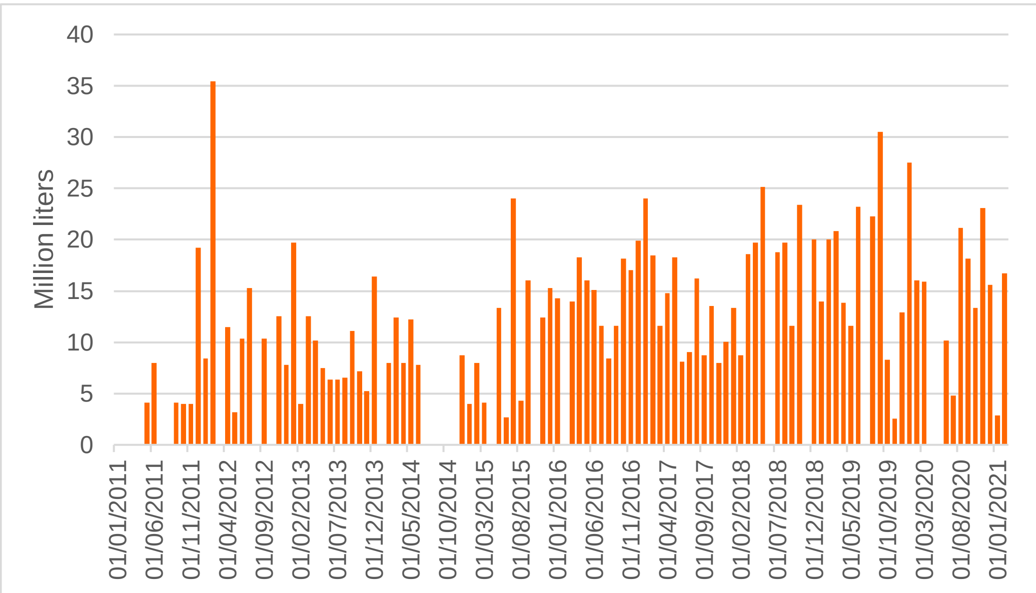
Figure 120: Ethanol consumption in Peru, 2009-2020



Source: U.S. Department of Agriculture Gain Report Biofuels Annual, SGS INSPIRE Compilation

Peru has traditionally focused on supplying the EU market with ethanol, while for the domestic market Peru has relied on U.S. ethanol for the most part and Brazilian ethanol occasionally.

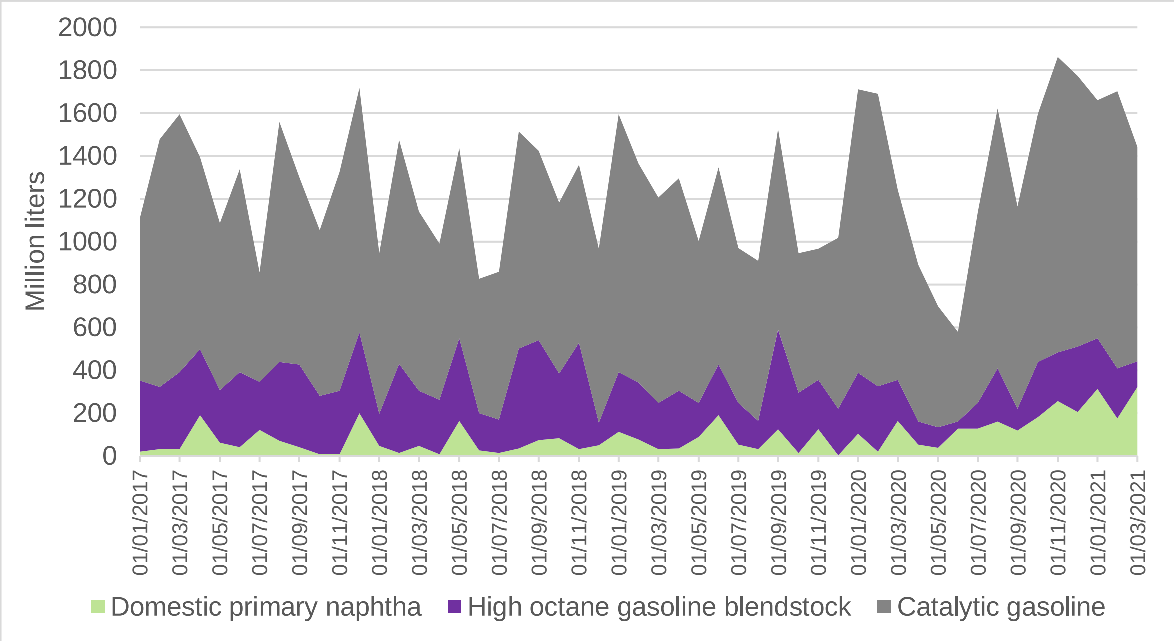
Figure 121: U.S. ethanol exports to Peru, million liters



Source: EIA, 2021

According to the Ministry of Energy and Mines of Peru, the main blending components used to produce gasoline in Peru are the following:

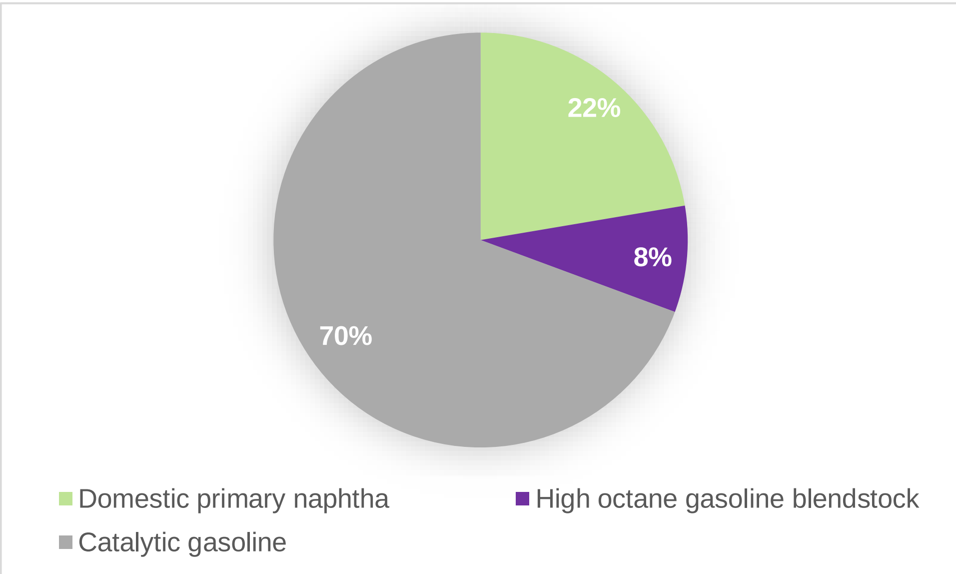
Figure 122: Gasoline blendstocks in Peru, 2017-2021



Source: Supervisory Agency for Investment in Energy and Mining of Peru (OSINERGMIN), SGS INSPIRE Compilation

Considering the latest, the gasoline blending components in Peru should be as presented in Figure 123.

Figure 123: Gasoline blending components in Peru



Source: Ministry of Energy and Mines, SGS INSPIRE Compilation

URUGUAY

REGULATIONS

Gasoline

Current gasoline specifications are defined in Resolution 110/014, published in the Official Journal on June 18, 2014. This Resolution modified the olefins parameters, reducing the permitted content from 25% v/v to 20% v/v. Resolution 110/014 superseded Resolution 150/008 of November 18, 2008, which regulated the specifications of all fuels in Uruguay.

Resolution 150/008 indicated that as of October 1, 2012, the maximum permitted sulfur content in automotive gasoline was 30 mg/kg. It also specified three gasoline grades: RON 87, RON 95, and RON 97. The more recent Resolution 110/2014 included only RON 93 and RON 97 gasoline; RON 87 gasoline was phased out.

Reid vapor pressure (RVP) values depend on the season. The maximum RVP level in summer (November to March) is 10.5 psi (72.4 kPa) and in winter (April to October) is 12 psi (82.7 kPa).

ANCAP, the National Administration of Fuels, Alcohol, and Portland, started production of gasoline RON 95 and RON 97 compliant with upgraded specifications to enable Euro 5 vehicle exhaust emissions standards in 2019.

ANCAP is the only producer and importer of fuels in Uruguay. Gasoline produced and imported by ANCAP has better quality than what is required in national specifications.

Ethanol

Ethanol (E100) is not used as a neat fuel, but it can be blended with gasoline up to 10% v/v.

The Regulatory Body for Energy and Water Services (URSEA) does not regulate the quality of ethanol specifically, but the Uruguayan Institute of Technical Norms (UNIT) has issued two standards, one for hydrous ethanol (UNIT Standard 1124:2010 of September 30, 2010) and another for anhydrous ethanol to be blended with gasoline (UNIT Standard 1122:2009 of November 30, 2009). Ethanol sold on the Uruguayan market should comply with the limits included in those standards according to Law 18.195 on biofuels, regulating their promotion and production, supply and use.

Ethanol blending in Uruguay began in 2007 when Law 18.195 was implemented. Law 18.195 required ANCAP to incorporate domestic ethanol up to 5% v/v until December 31, 2014, on a voluntary basis. The 5% v/v was implemented as a mandate only as of January 1, 2015. After that date and until today, the permitted maximum ethanol content has been 10% v/v.

CURRENT FUEL QUALITY STANDARDS AND OBJECTIVES

ANCAP is already producing Euro 6 enabling gasoline, although gasoline specifications are less stringent and only reach a level of Euro 4/Euro 5 enabling gasoline specifications. Uruguay does not have specific regulations for light-duty vehicles in place but has Euro III vehicle emissions standards for heavy-duty vehicles enforced.

COMPARISON AGAINST STANDARDS

The differences between the specifications in Resolution 110/2014 and the specifications followed by ANCAP are in Figure 124. Actual quality of gasoline in Uruguay in winter 2019/2020 is also included. As mentioned, quality of gasoline produced by ANCAP is very similar to Euro 6 enabling specifications, applied currently in the EU. Based on the tests results performed on actual quality, octane is the only parameter that does not fulfill European specifications. Other parameters such as benzene, aromatics and olefins are below the European maximum levels.

Actual quality shown in the table is the average values of 7 samples: 4 samples of premium RON 95 E10 and 3 samples of premium plus RON 97 E10 collected in Montevideo and Nueva Palmira.

Figure 124: Comparison between Uruguayan governmental and industry specifications, EU Euro 6 enabling specifications and actual quality data

	Uruguay Specifications				Uruguay actual gasoline Winter quality 2019/2020 Average		EU Specifications			
Implementation Date	2019		2020		N/A		2017			
Selected Grade	Super 95 30-S	Premium 97 30-S	Super 95 30-S	Premium 97 30-S	Super 95 30-S	Premium 97 30-S	RON 95 E5	RON 95 E10	RON 98 E5	RON 98 E10
Name	Resolution 110/2014		ANCAP		Average values		EN 228:2012 + A1:2017 (Euro 6 enabling)			
Benzene Content	< 1 %v/v				0.54% v/v		< 1 %v/v			
Aromatics	< 40 %v/v		< 35 %v/v		30.8% v/v		< 35 %v/v			
Olefin s	< 20 %v/v		< 18 %v/v		10.4% v/v		< 18 %v/v			
Lead Content	< 0.005 g/l				<0.0025 g/l		< 5 mg/l			
Manganese	< 2.5 mg/l				< 0.1 mg/l		< 2.0 mg/l			
RON	> 95	> 97	> 95	> 97	**94.3**	**95.8**	> 95	> 95	> 98	> 98
MON	> 82	> 84	> 85		84.4	**84.7**	> 85	> 88	> 85	> 88
Sulfur Content	< 30 mg/kg		< 10 mg/kg		6.1 mg/kg		< 10 mg/kg			
Oxygen Content	< 2.7 %m/m				-		< 2.7 %m/m	< 3.7 %m/m	< 2.7 %m/m	< 3.7 %m/m
Ethanol (EtOH)	<> 10 %v/v				10.9% v/v		< 5 %v/v	< 10 %v/v	< 5 %v/v	< 10 %v/v
RVP 37.8°C (Summer)	<> 72 kPa		<> 50-80 kPa		-		<> 60 - 70 kPa *Depends on the country, RVP is regulated in the EU Fuel Quality Directive			
RVP 37.8°C (Winter)	<> 83 kPa		<> 45-67 kPa		58 kPa					
Ethers 5 or more C Atoms	-				0% v/v		Based on oxygen content	< 22 %v/v	Based on oxygen content	< 22 %v/v

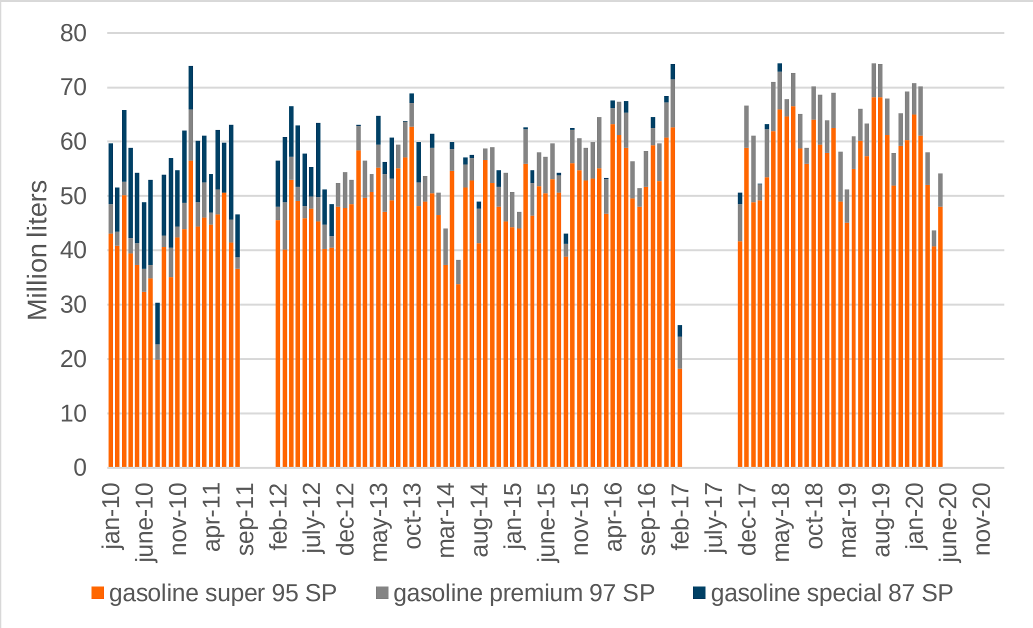
*In orange the values that would not comply with EU specifications and in blue the values that do not comply with Uruguayan specifications.

Source: Uruguayan and EU specifications, SGS Worldwide Fuel Survey, 2021

BLENDSTOCK ANALYSIS

Total gasoline production in Uruguay varies between 70 and 50 million liters per month, but the refinery yield can be lower. In 2020, RON 95 gasoline was approximately 90% of the total production and RON 97 was 10%.

Figure 125: Gasoline production in Uruguay per octane grade

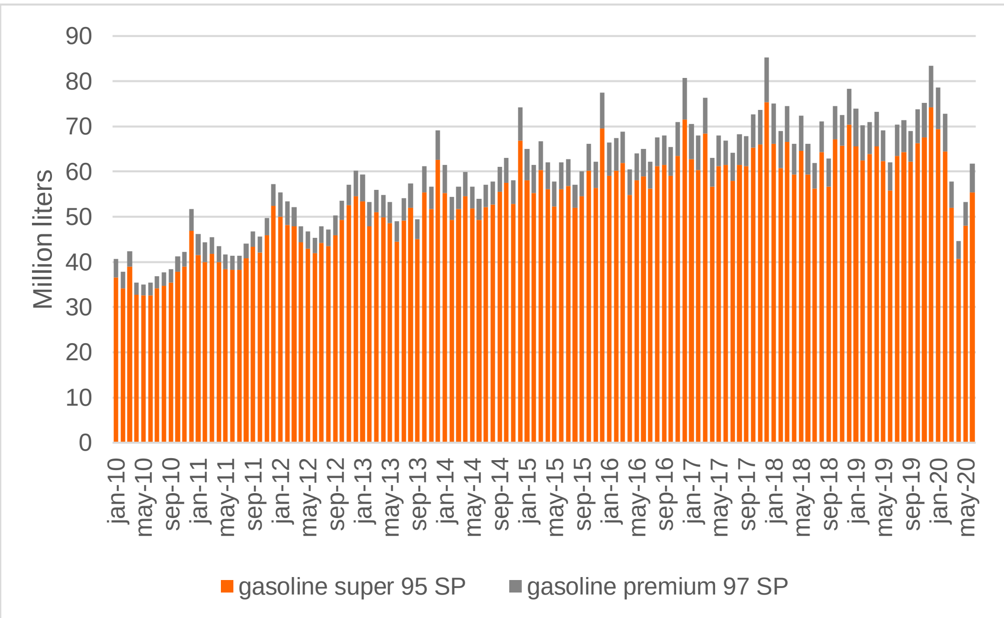


*SP: super

Source: Ministry of Industry, Energy and Mining, SGS INSPIRE Compilation

Gasoline demand has increased steadily in Uruguay in recent years. It reached 80-70 million liters before the COVID-19 pandemic, when demand dropped to 2010 values.

Figure 126: Gasoline demand in Uruguay per octane grade

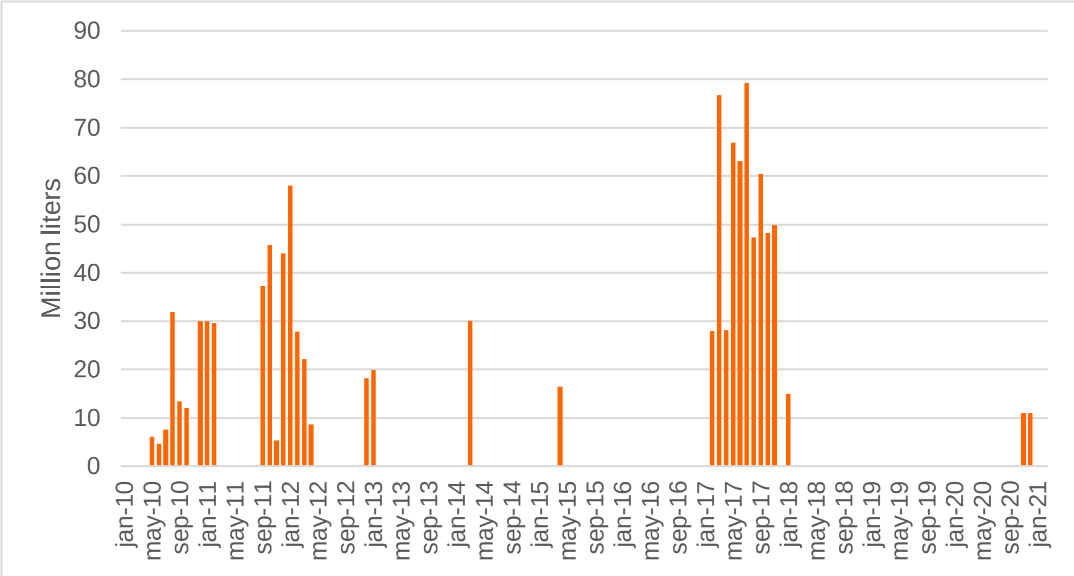


Source: Ministry of Industry, Energy and Mining, SGS INSPIRE Compilation

Uruguay needs gasoline imports when the domestic refinery cannot meet internal demand. This usually only happens when the refinery needs to stop for maintenance.

According to United Nations Comtrade, in 2020 gasoline imports to Uruguay came from United States, and mostly Belgium and Germany.

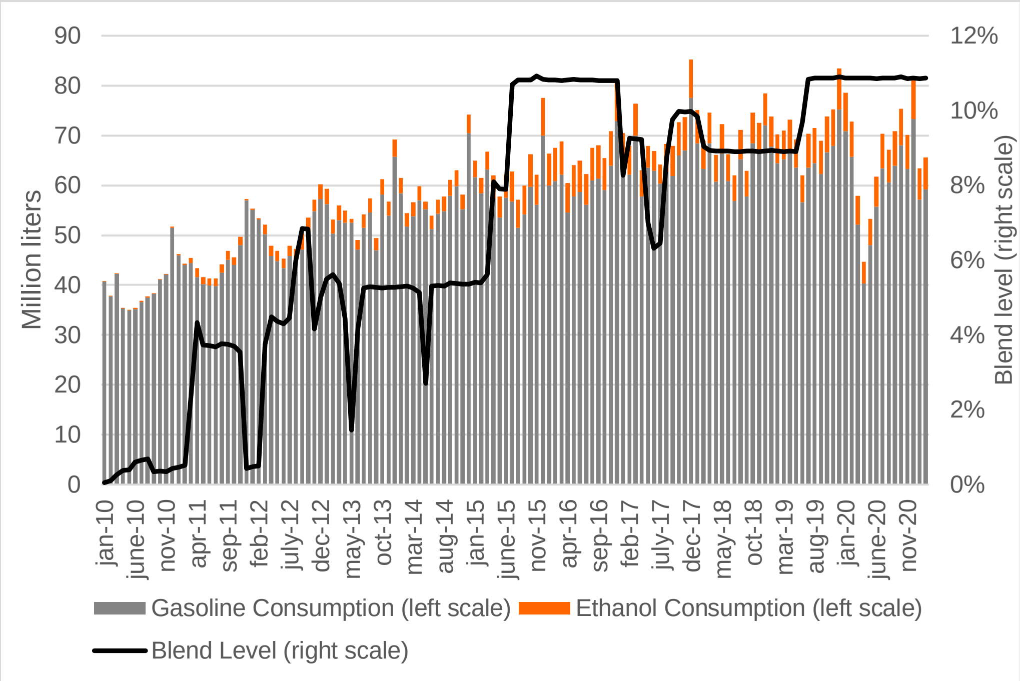
Figure 127: Gasoline imports to Uruguay, 2010-2020



Source: Ministry of Industry, Energy and Mining, SGS INSPIRE Compilation

The following figure shows the volume of ethanol blended in gasoline since 2010. It has been steadily growing since then. However, in some months very little ethanol was blended - this is because ethanol blending depends entirely on the domestic supply and when there is a shortage of ethanol it is reflected in low ethanol blends. In 2015, when the 5% v/v blend mandate became official, and a new ethanol facility was commissioned, there was a significant increase in the volume of ethanol blended in gasoline. At the time of writing this report (August 2021), almost 11% v/v of ethanol is blended, regardless of the gasoline changes in consumption over the months. This is above the 10% v/v mandate established.

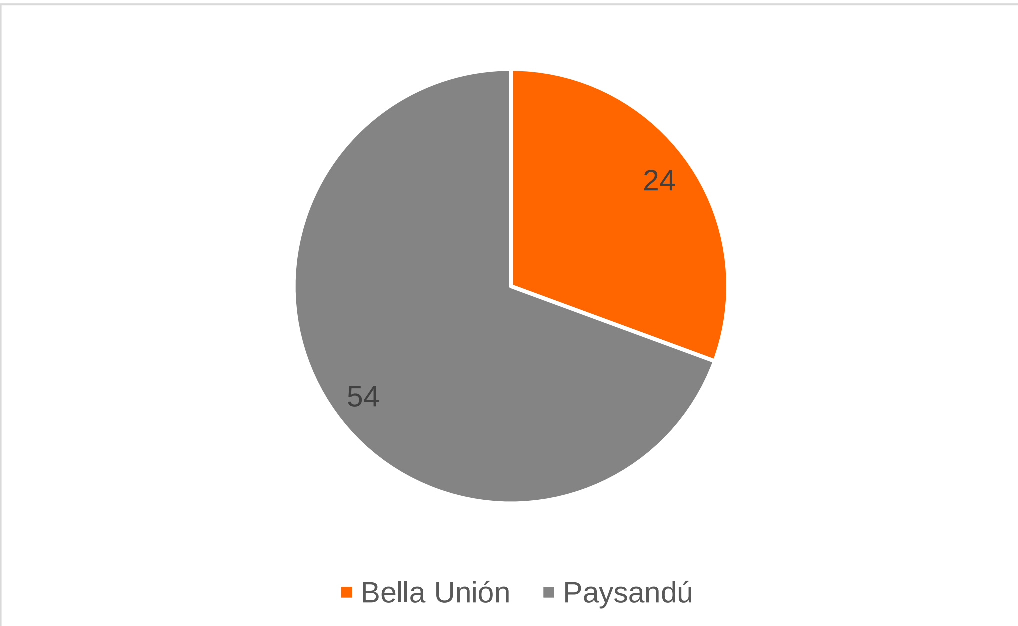
Figure 128: Ethanol blended in gasoline in Uruguay, 2010-2020



Source: Ministry of Industry, Energy and Mining, SGS INSPIRE Compilation

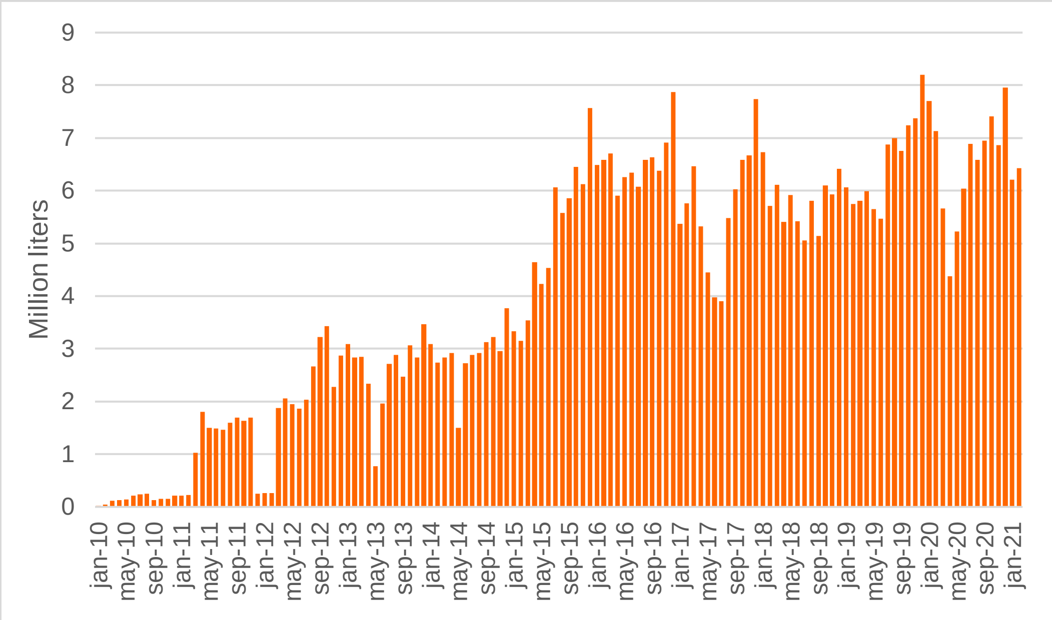
There are two ethanol plants in Uruguay, Bella Unión in Artigas (30 million liters production capacity), and Paysandú (70 million liters production capacity). The feedstocks used are sugarcane in Bella Unión and sorghum, barley, corn, and wheat in Paysandú. Both plants are owned by ALUR (Alcohols of Uruguay), the biofuels branch of the ANCAP. Figures 129 and 130 below indicate ethanol production and consumption in Uruguay.

Figure 129: Ethanol production per facility in 2020 in Uruguay (million liters)



Source: ANCAP, SGS INSPIRE Compilation

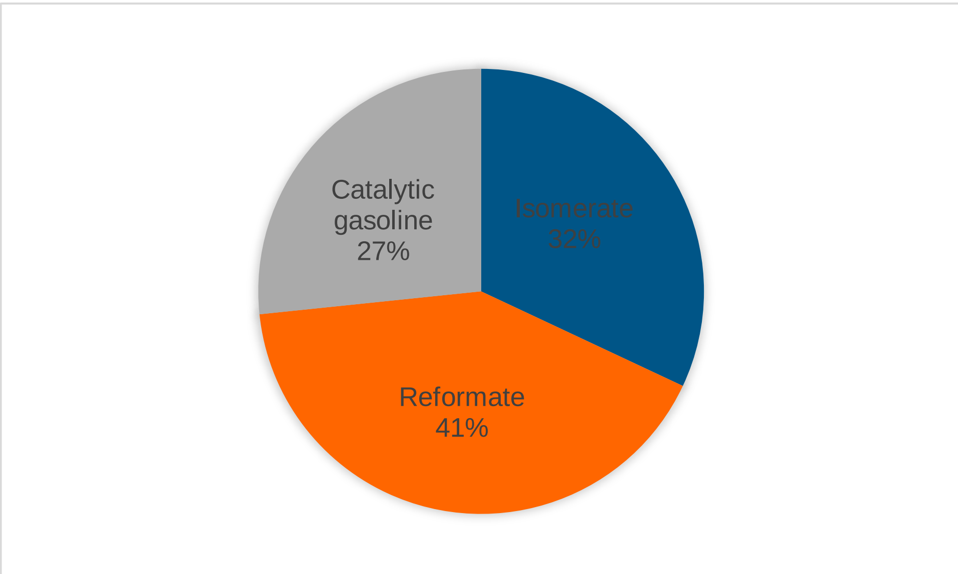
Figure 130: Ethanol consumption in Uruguay, 2010-2020



Source: Ministry of Industry, Energy and Mining, SGS INSPIRE Compilation

Since its creation, the ANCAP has had the monopoly in Uruguay on both the importation and refining of crude oil and its derivatives. Uruguay has less refining capacity than other Latin American countries like Argentina or Chile and mainly produces catalytic, isomerate and reformate as gasoline components.

Figure 131: Gasoline blending components produced in Uruguay



Source: ANCAP, SGS INSPIRE Compilation

SECTION 2: GASOLINE COMPONENT OPTIMIZATIONS FOR ETHANOL BLENDING

This section analyzes the results of the blend optimization model and shows how the increase of ethanol blend could optimize the blending components mix for each country.

The blending model seeks to minimize the price of a finished gasoline generated with the model, based on the prices of its components. In addition, the model seeks compliance with the quality parameters established, using the available gasoline blending components in the selected country. The model also optimizes the price of the blendstock using quality restrictions. These restrictions allow the blend to comply with the properties established in the finished gasoline. The model works with volumetric composition (% v/v) of the components. The blending components and their maximum quantity are restricted according to their availability in the selected country.

Figure 132 shows the prices that have been considered for the gasoline blending components in the model.

Figure 132: Prices for gasoline blending components used in the optimization model in 2019

	Price (USD/gal)
MTBE FOB USG	1.9
Alkylate FOB USGC barge	1.8
Reformate FOB USGC barge	1.8
Normal butane	0.7
C5-400 Catalytic gasoline	1.6
Coker naphtha	1.1
Isobutane	0.8
C5 Isomerate	1.6
Normal pentane	0.7
Gasoline RBOB 83.7 USGC Houston prompt pipeline	1.6
Gasoline RBOB 91.3 USGC Houston prompt pipeline	1.7

Source: HCX

With the Excel optimization tool, Solver, multiple combinations of components are evaluated, and the results of the equations are compared with the properties of the finished gasoline.

After multiple iterations, the model obtains the % v/v of the components to be blended with ethanol, that meet all the quality and price restrictions.

The blending components used in the model are mostly reformate, catalytic gasoline, isobutane, isomerate, alkylate and ethanol. However, there are some countries (i.e. Argentina, Ecuador, Mexico, Peru) that produce other blendstocks, as shown in Section 1. In Figure 133, blendstocks included in the model and other minor blendstocks produced in Latin American refineries are defined according to distillation points. Components with similar features could be replaced in the process of blending components to produce gasoline.

Figure 133: Gasoline blending components comparison according to distillation points

Gasoline blending component	Definition
Reformate	The complex combination of hydrocarbons obtained in a hydrofiner-powerformer process and boiling in a range of approximately 27°C to 210°C (80°F to 410°F)
High-octane blendstock	A complex high octane combination of hydrocarbons obtained by the catalytic dehydrogenation of a naphthenic naphtha. It consists predominantly of aromatics and non-aromatics having carbon numbers mostly in the range of C5 through C11 and boiling in the range of approximately 45°C to 185°C (113°F to 365°F)
Hydrocracked gasoline	A complex combination of hydrocarbons from distillation of the products from a hydrocracking process. It consists predominantly of saturated hydrocarbons having carbon numbers mostly in the range of C4 through C10 and boiling in the range of approximately minus 20°C to 180°C (-4°F to 356°F)
Catalytic gasoline	A complex combination of hydrocarbons produced from the distillation of products from a catalytic reforming process. It consists of predominantly aromatic hydrocarbons having carbon numbers mostly in the range of C7 through C12 and boiling in the range of approximately 90°C to 230°C (194°F to 446°F)
Alkylate (light)	A complex combination of hydrocarbons produced by distillation of the reaction products of isobutane with monoolefinic hydrocarbons usually ranging in carbon numbers from C3 through C5. It consists of predominantly branched chain saturated hydrocarbons having carbon numbers in the range of C7 through C10 and boiling in the range of approximately 90°C to 160°C (194°F to 320°F)
Isomerate	A complex combination of hydrocarbons obtained from catalytic isomerization of straight chain paraffinic C4 through C6 hydrocarbons. It consists predominantly of saturated hydrocarbons such as isobutane, isopentane, 2,2-dimethylbutane, 2-methylpentane, and 3-methylpentane. The boiling range is approximately 40°C to 140°C (104ºF to 284ºF)
Isobutane	Compound included in isomerate
Domestic primary naphtha	Refined, partly refined, or unrefined petroleum products produced by the distillation of natural gas. It consists of hydrocarbons having carbon numbers predominantly in the range of C5 through C6 and boiling in the range of approximately 100°C to 200°C (212°F to 392°F)
Coker naphtha	A complex combination of hydrocarbons obtained by fractionation from hydrodesulphurized coker distillate. It consists predominantly of hydrocarbons having carbon numbers mostly in the range of C5 to C11 and boiling in the range of approximately 23°C to 196°C (73°F to 385°F)

Source: CONCAWE, Petroleum Substances Inventory

In countries with significant gasoline imports, the blending components mix is an average of domestic manufactured products and gasoline components usually imported.

In net importing countries, the blending component mix is similar to the composition of conventional gasolines produced in the U.S., as it is the most important gasoline exporter in the region.

Economics of blending components optimization

According to the study The Impact of Ethanol Blending on U.S. Gasoline Prices performed by the U.S. National Renewable Energy Laboratory in 2008, ethanol blending in the U.S. was keeping U.S. retail gasoline prices about 17 cents per gallon lower than they would be with no ethanol.

Another study from the University of California, Cost Benefit Analysis of MTBE and Alternative Gasoline Formulations, concludes that the costs of using MTBE outweigh the benefits, considering air and water quality policies. There are alternative gasoline formulations that can achieve the air quality benefits of CaRFG2 without the additional risks to California's water resources, and costs of water treatment. The Californian policy gasoline, CaRFG2, blended with ethanol has net costs in achieving air quality benefits. CaRFG2 with MTBE has the highest net costs for achieving air quality benefits. The most important cost factors for MTBE are the cost of water treatment to avoid human health damages, the direct cost increase, and the potential lost value of recreational boating.

Key Takeaways

The optimized blending components mix for countries with simple refineries is composed mainly of reformate, catalytic gasoline and isomerate. In the case of countries with more complex refineries or high amounts of imports, the blending components mix is composed of reformate, catalytic gasoline, isomerate, isobutane and alkylate, in different proportions.

The addition of ethanol usually reduces catalytic gasoline before reformate. This is because their prices are similar (reformate is a bit more expensive than catalytic gasoline) but reformate has a higher octane, which presents an advantage to the blending components mix.

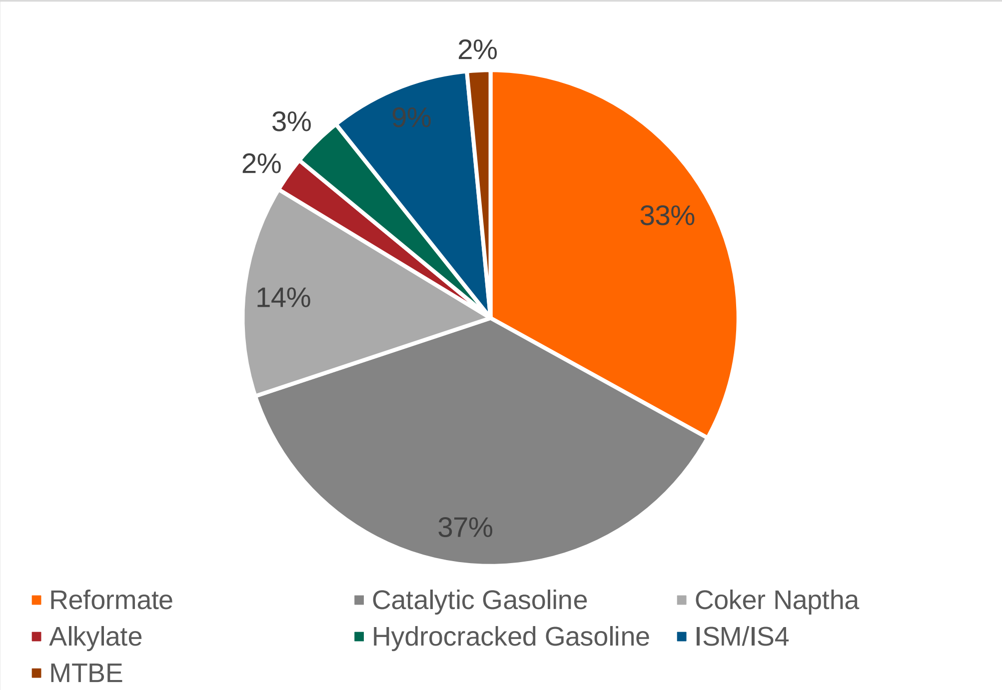
The addition of ethanol to the optimized blending components mix provokes that less expensive cuts can be used when ethanol is added, since ethanol increases octane and has no sulfur or hydrocarbons. Also, there is a reduced need to add alkylate, which is on of the most expensive blending components, and its producing process (the alkylation unit) is found less frequently in refineries than reforming or FCC units. As can be seen in several countries, alkylate is the blending component that exits the mix before when ethanol is added.

In countries where ethanol is not used, and MTBE is the main blending component to increase octane, MTBE can be substituted by ethanol if RVP is controlled and beyond specifications. If RVP actual quality data is well-below regulatory limits, this replacement should be feasible.

Argentina

In Figure 135, the optimized blendstock mix for gasoline production is depicted, as well as the optimized blendstock mix when ethanol is added for the E10, E15, E20, E25 and E30 grades. It is compared with the current gasoline blendstock mix in Argentina.

Figure 134: Gasoline blendstock mix in Argentina

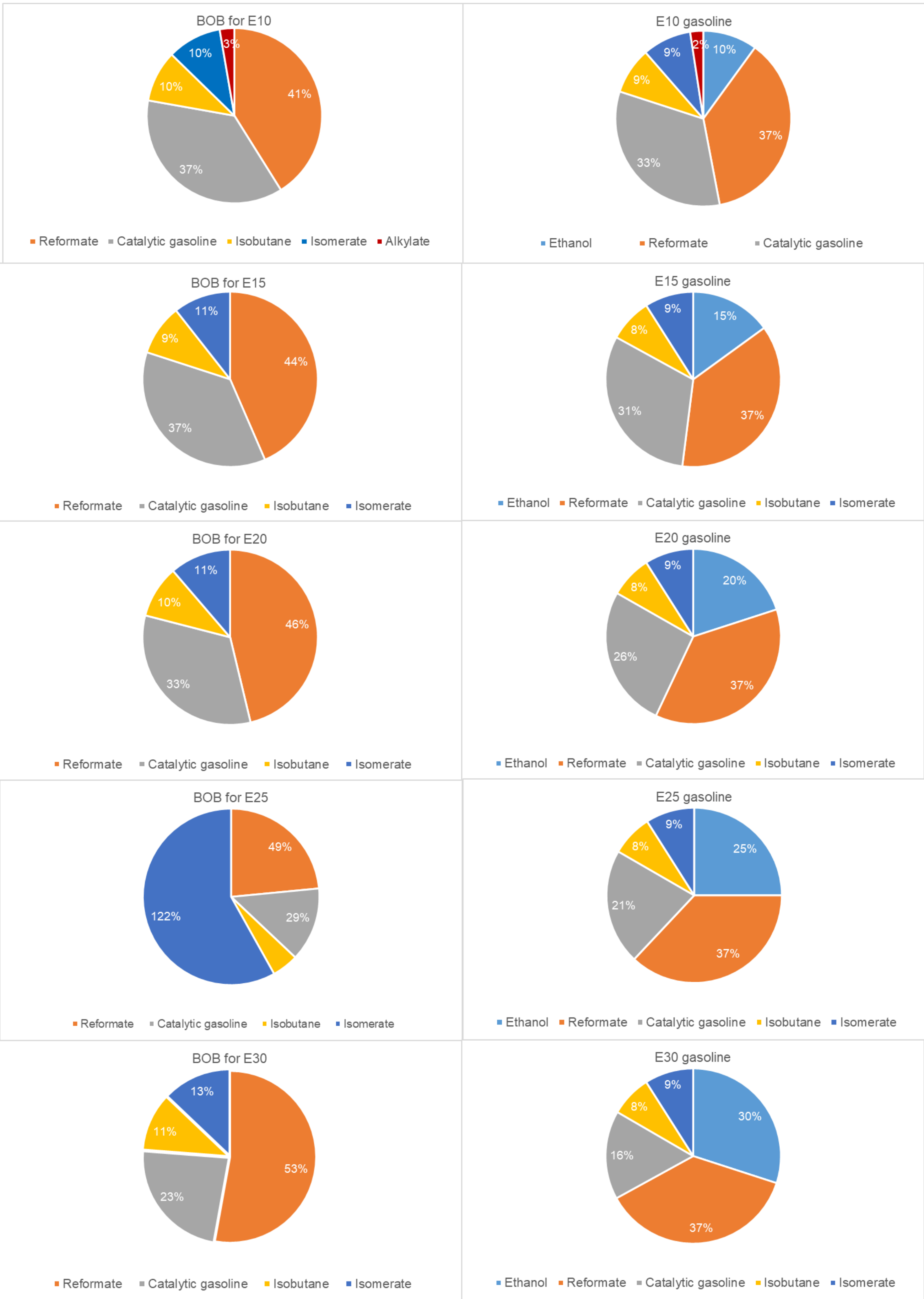


Source: HCX with Wood Mackenzie PennEnergy Research and Oil and Gas Journal Data

As can be seen above, the current average blending components mix for gasoline production used in Argentina, seen in earlier sections, and the optimized mix is quite alike. Reformate and catalytic gasoline are included in similar proportions, and there is also presence of isomerate. The main difference is the isobutane, which should substitute Coker naphtha, currently used in Argentina. When the ethanol content is increased, catalytic gasoline decreases, and reformate is maintained for the BOB used up to E30. This is due to the fact that catalytic gasoline is expensive, it is the component produced in the highest amounts in Argentina and its octane is lower than reformate's.

The government of Argentina plans to reduce sulfur in gasoline from 150 mg/kg to 50 mg/kg in 2024 only because the refineries need time to implement changes to comply with sulfur reduction in new standards. The increase of ethanol content in the blendstock mix can help reduce sulfur and would accelerate plans to set stricter specifications.

Figure 135: Optimized blendstock mix for ethanol blends and final composition of ethanol grades



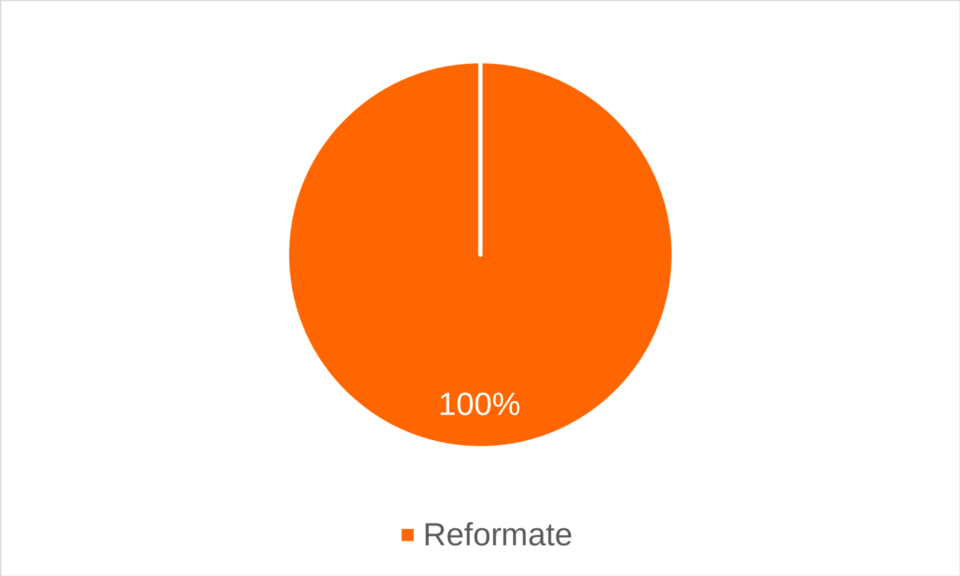
Source: HCX

Bolivia

In Figure 137, the optimized blendstock mix for gasoline production is depicted, as well as the optimized blendstock mix when ethanol is added for the E10, E15, E20, E25 and E30 grades.

The gasoline component used primarily is reformate.

Figure 136: Gasoline blendstock mix in Bolivia

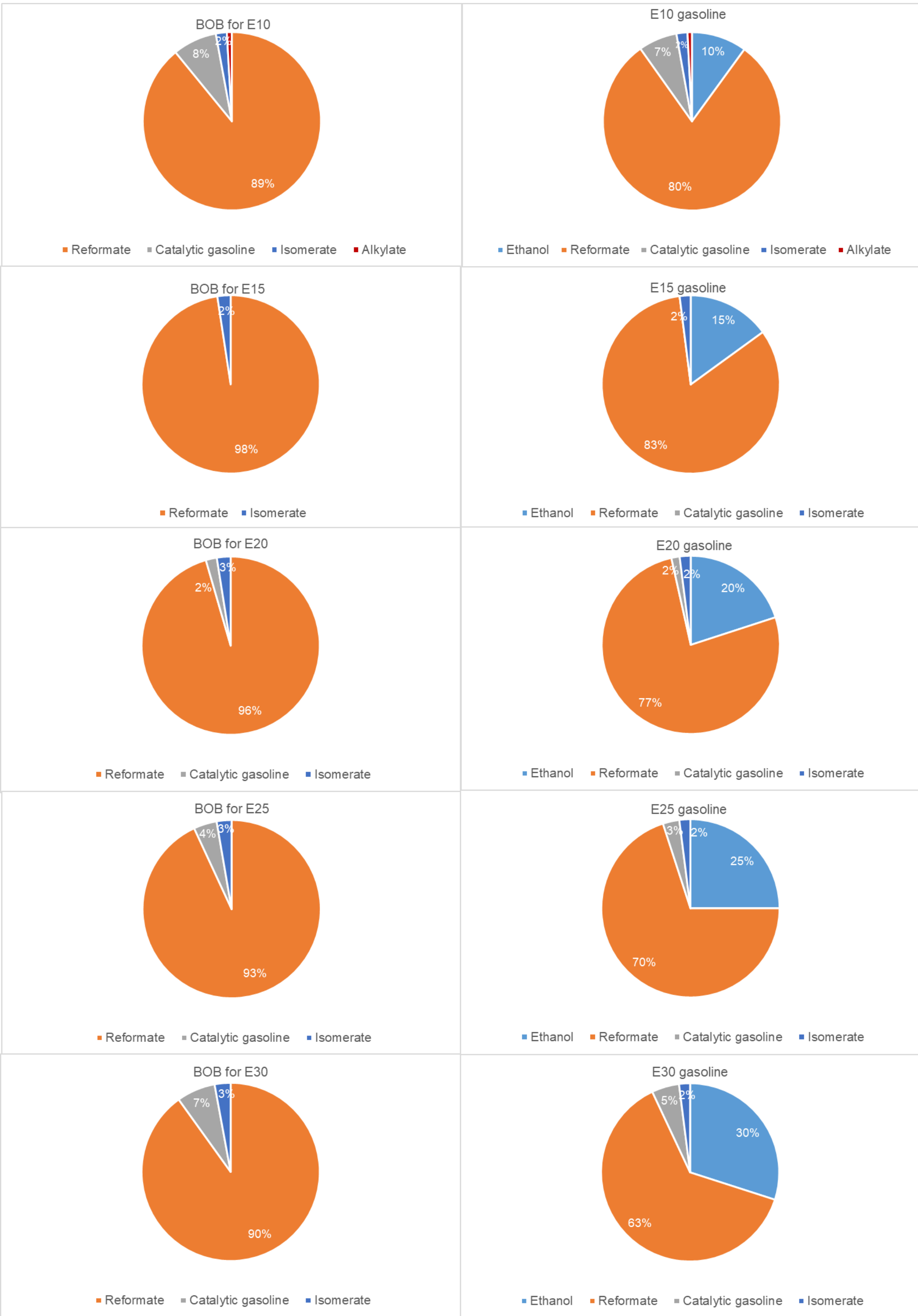


Source: HCX

There is almost no difference between the optimized mix shown below and the current gasoline blending components in Bolivia (shown here). Currently mostly reformate is used in Bolivia, due to the simplicity of its refineries. Additionally, some quantities of isomerate and catalytic gasoline are used. Bolivian refineries can produce gasoline with less than 500 mg/kg sulfur, which is the current regulatory limit, but they cannot produce high octane gasoline.

The success story of introducing E12 in Bolivia shows that a wider implementation of ethanol blends is feasible. The increase of a higher share of ethanol in the blendstock mix of Bolivia can help reduce sulfur and increase octane. It would also reduce the need of including more expensive refining products, which Bolivia lacks.

Figure 137: Optimized blendstock mix for ethanol blends and final composition of ethanol grades

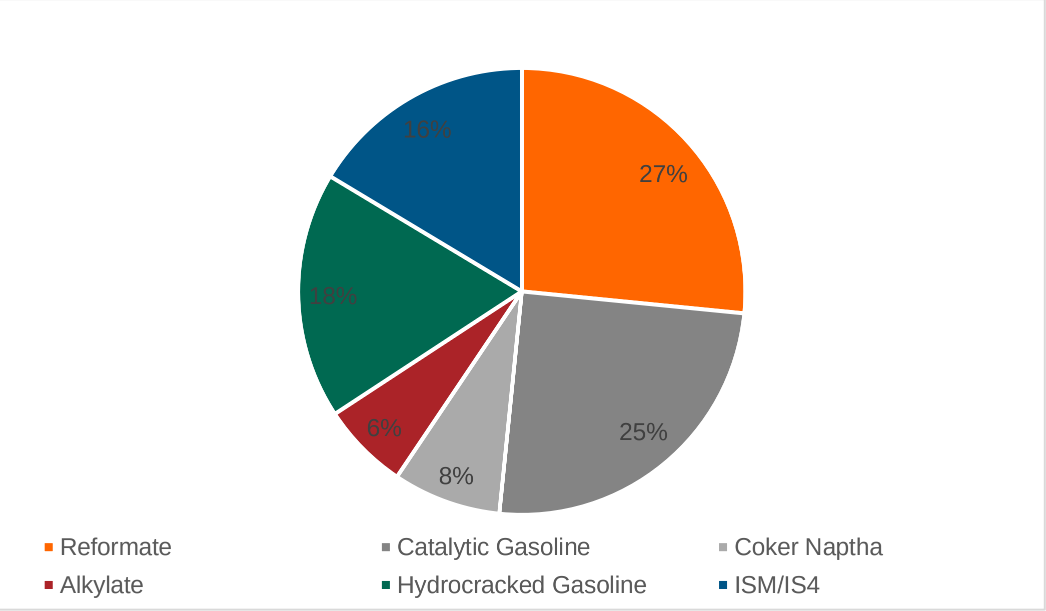


Source: HCX

Chile

In Figure 139, the optimized blendstock mix for gasoline production is depicted, as well as the optimized blendstock mix when ethanol is added for the E10, E15, E20, E25 and E30 grades. It is compared with the gasoline blendstock mix in Chile, shown as well below.

Figure 138: Processed products in the Chilean refineries except for MTBE

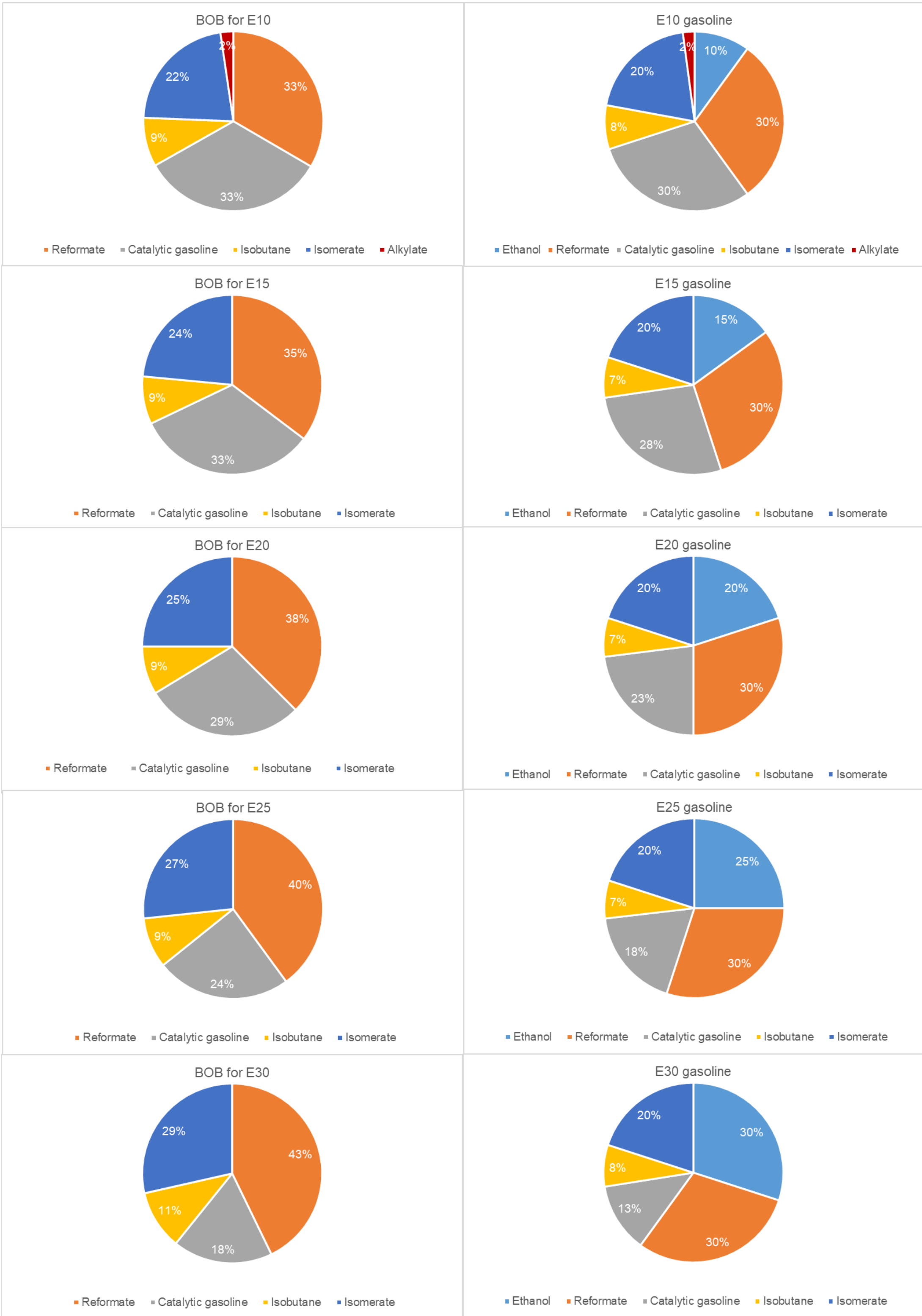


Source: HCX with Wood Mackenzie PennEnergy Research and Oil and Gas Journal data

The Chilean refining products compared with the mix derive of the optimization model differ in several products. Coker naphtha, Alkylate, and Hydrocracked gasoline are produced in Chile, but isomerate content is high in the optimized mix. Coker naphtha and Hydrocracked gasoline could be replaced by other simpler hydrocarbons like isobutane to improve gasoline quality. The optimized mix when ethanol is added reduces the content of isomerate, catalytic gasoline, reformate, and isobutane, since Chile can produce all four blending components. Alkylate is not included in the optimization mix, being the most expensive cut from the domestically produced components.

The blending components mix does not contemplate the use of MTBE, but this is significant in Chile. Ethanol could replace MTBE as octane booster, but RVP should be controlled. RVP would be the main parameter affected by the replacement of MTBE with ethanol, which is very important because of air pollution in Santiago, but base gasoline RVP in Chile is quite low. The replacement of MTBE with ethanol would also help reduce aromatics and olefins content.

Figure 139: Optimized blendstock mix for ethanol blends and final composition of ethanol grades

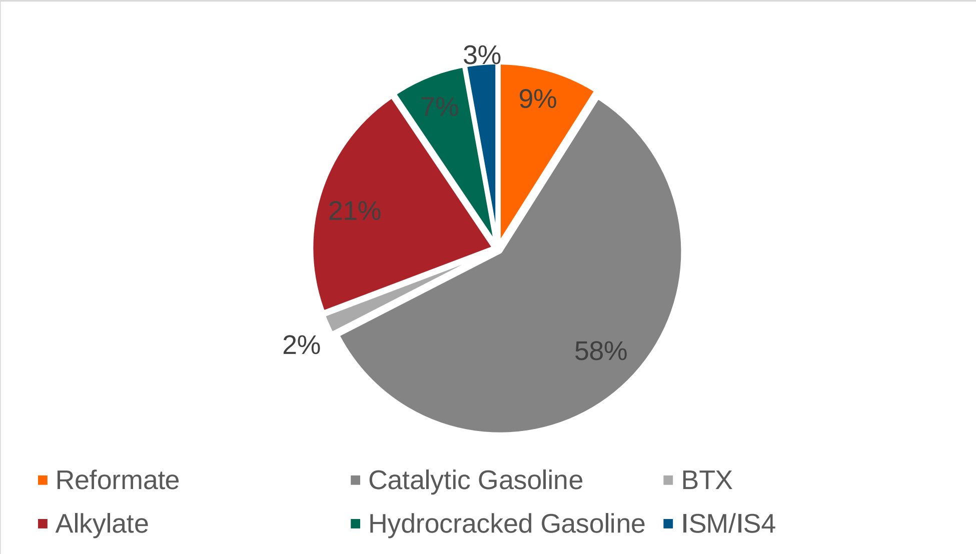


Source: HCX

Colombia

In Figure 141, the optimized blendstock mix for gasoline production is depicted, as well as the optimized blendstock mix when ethanol is added for the E10, E15, E20, E25 and E30 grades. This is compared to the gasoline blendstock mix in Colombia.

Figure 140: Processed products in the Colombian refineries, 2020

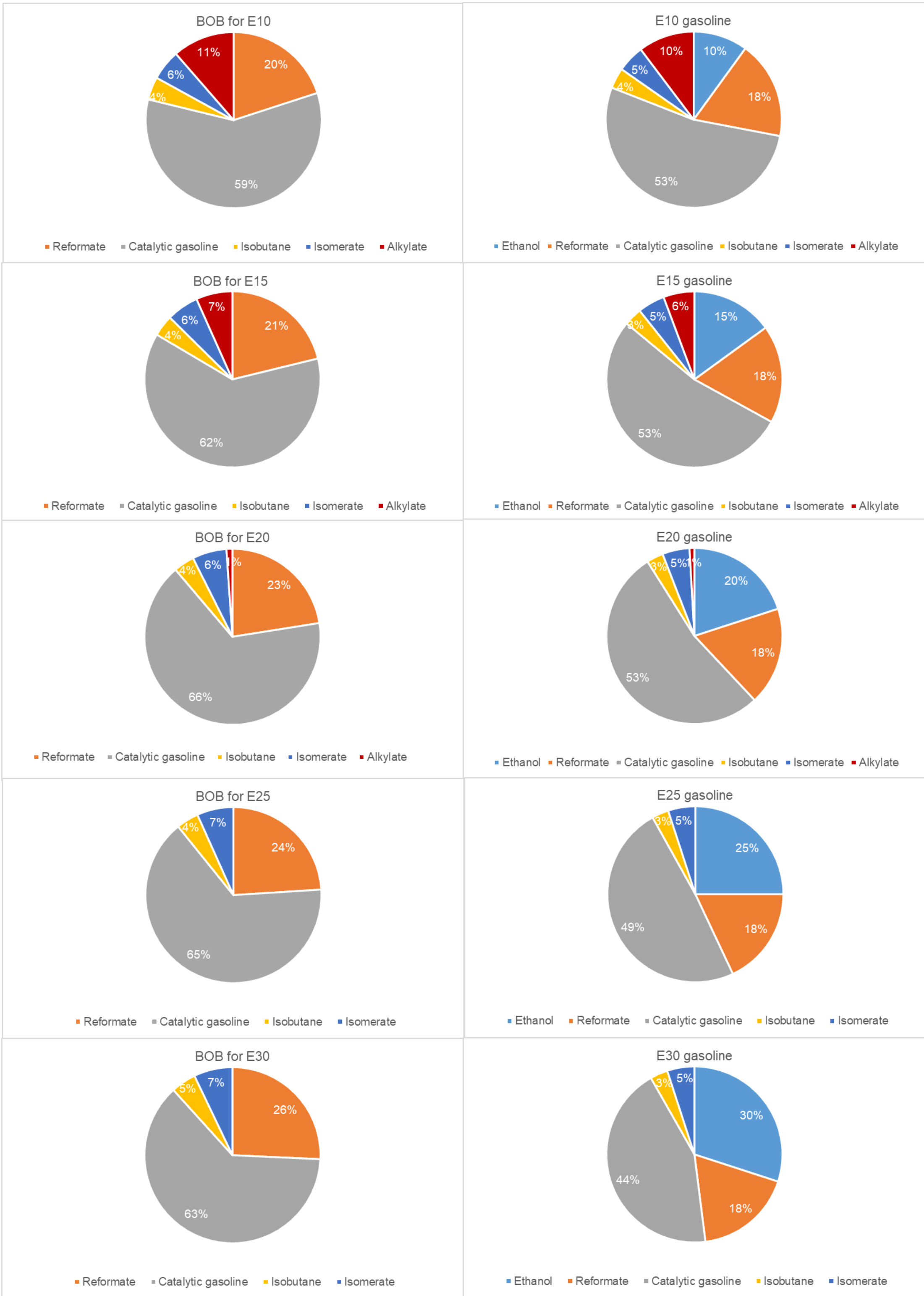


Source: HCX with Wood Mackenzie PennEnergy Research and Oil and Gas Journal data

The most significant change between the product output from the refinery of Cartagena (shown here) and the optimized blendstock mix shown below is the content of alkylate and reformate. The optimized blend contains more reformate and less alkylate compared to the products obtained by ECOPETROL. The higher addition of ethanol in gasoline in Colombia may reduce the amount of catalytic gasoline and alkylate, catalytic gasoline because it is the most produced component in Colombia and its octane is lower than reformate's and alkylate because it is more expensive than reformate.

The government of Colombia has official plans to reduce sulfur in gasoline to 10 mg/kg and increase octane in 2030. This will only be feasible in nine years because refineries should be upgraded. Furthermore, Colombian refineries can't produce high octane gasoline, and they will only be able to increase octane producing by-products with higher aromatics content, as shown in future specifications. That is why the aromatics limit proposed in 2030 has increased. Adding more ethanol to gasoline would accelerate plans to reduce sulfur and increase octane, and there would be no need to increase the aromatics limit in the specifications.

Figure 141: Optimized blendstock mix for ethanol blends and final composition of ethanol grades



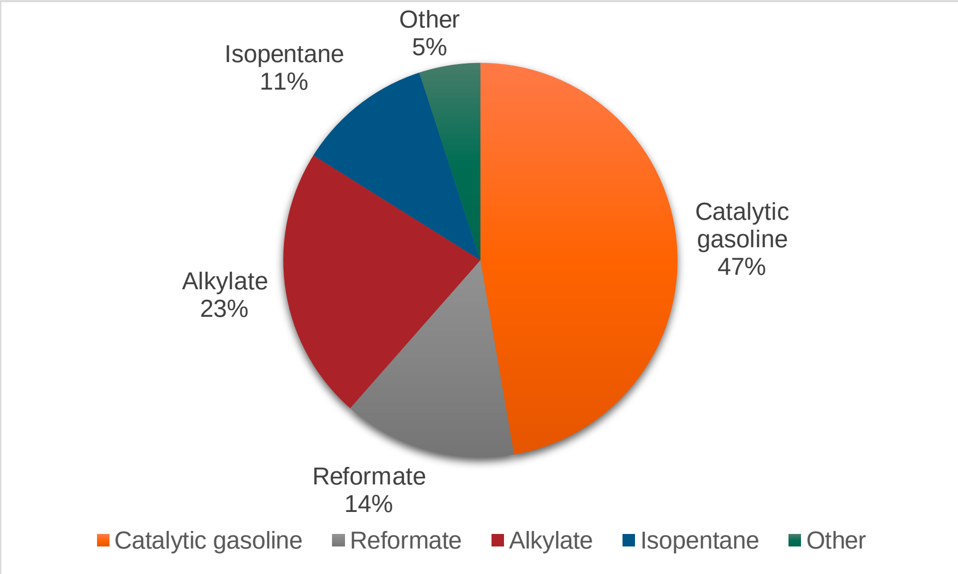
Source: HCX

Costa Rica

In Figure 143, the optimized blendstock mix for gasoline production is depicted, as well as the optimized blendstock mix when ethanol is added for the E10, E15, E20, E25 and E30 grades.

This is compared to the gasoline blendstock mix of Costa Rica, shown below.

Figure 142: Gasoline blending components produced in Costa Rica

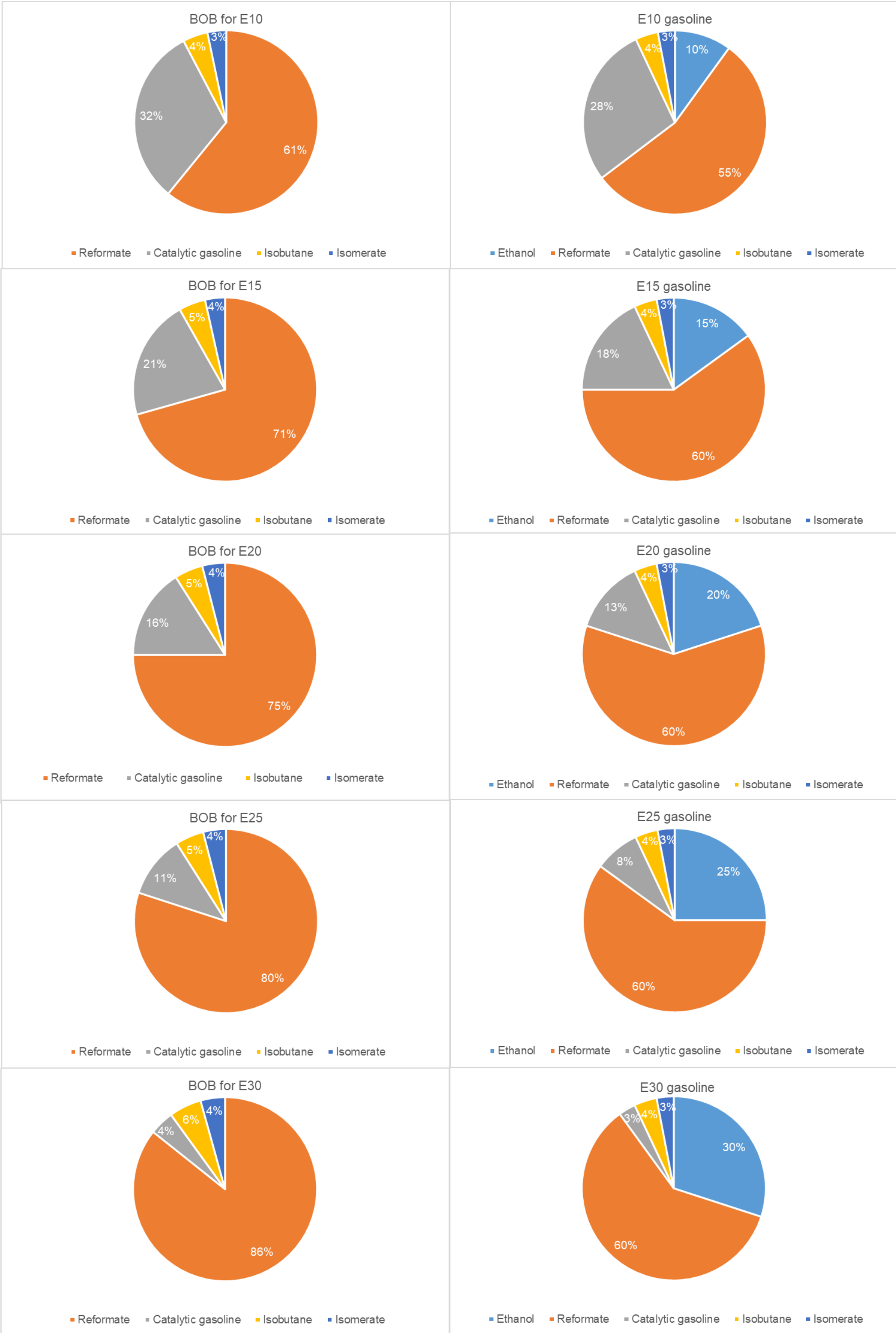


Source: SGS INSPIRE Compilation

The optimized blendstock mix is somewhat similar to the current gasoline blendstock mix in Costa Rica. Catalytic gasoline is the most used product at present although reformate is the most used blending component according to the optimized mix. Isobutane and isomerate are present in small quantities.

The addition of ethanol would imply the reduction of the need to add more expensive refining products to the gasoline blendstock mix, particularly alkylate. As can be seen below, the model eliminates alkylates in the optimization mix. Both catalytic gasoline and reformate are reduced when ethanol is added because they are the predominant components in the gasoline mix.

Figure 143: Optimized blendstock mix for ethanol blends and final composition of ethanol grades



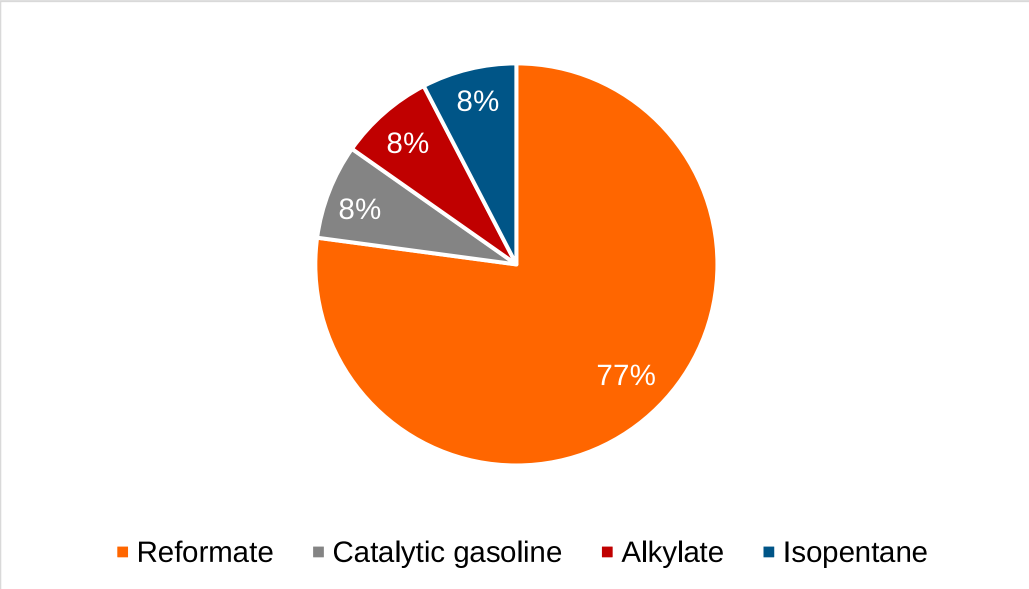
Source: HCX

Dominican Republic

In Figure 141, the optimized blendstock mix for gasoline production is depicted, as well as the optimized blendstock mix when ethanol is added for the E10, E15, E20, E25 and E30 grades.

This is compared to the gasoline blending components mix, shown below.

Figure 144: Gasoline blending components produced in Dominican Republic

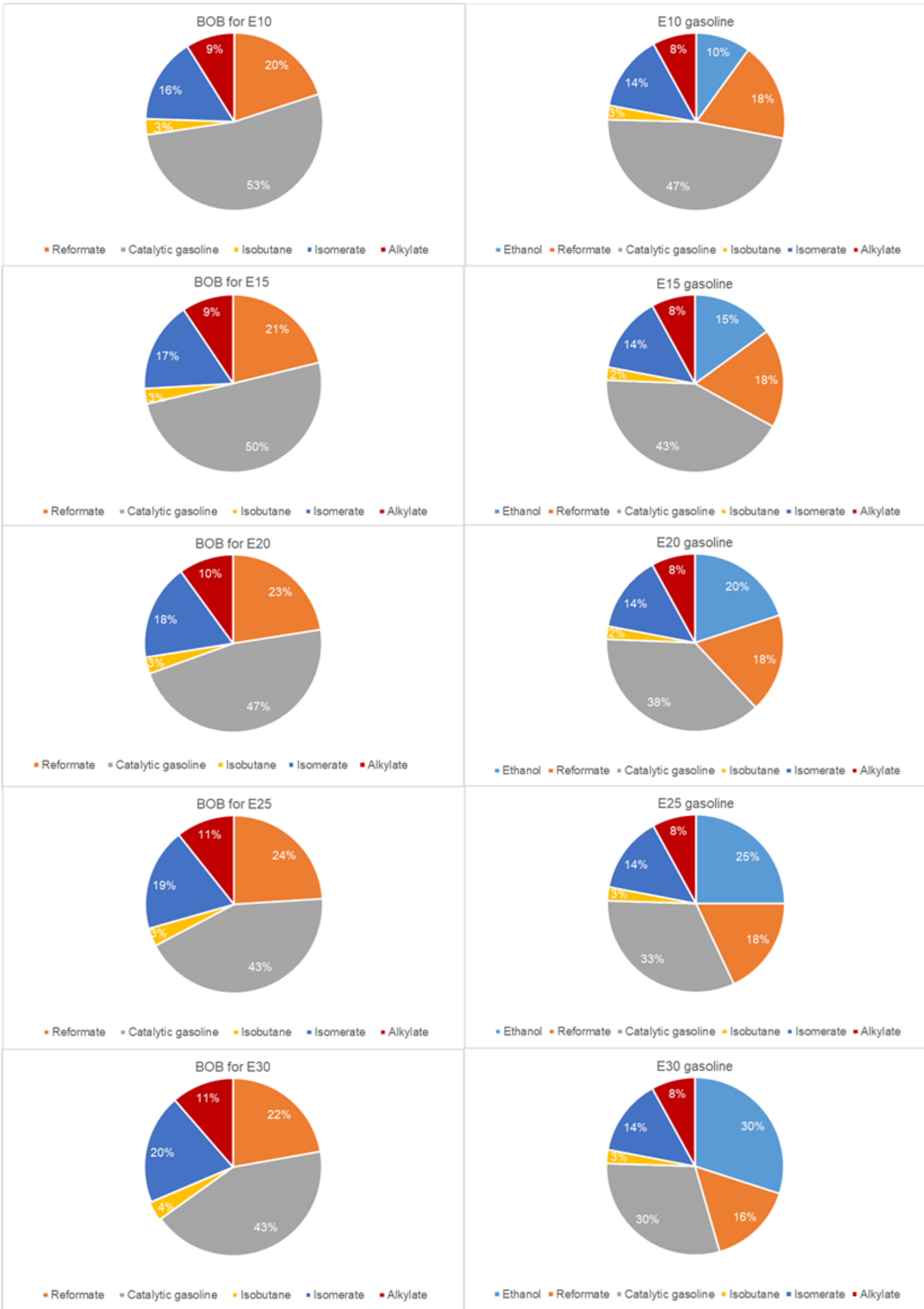


Source: Ministry of Trade, CEPAL, EIA, SGS INSPIRE Compilation

The difference of the current blendstock mix for gasoline production (shown here) and the optimized mix shown below is significant. Currently mostly reformate is used in the Dominican Republic, due to the simplicity of its refineries. In the optimized blending mix, catalytic gasoline, alkylate and isobutane are also present.

The increase of ethanol content in the blendstock mix can help reduce sulfur and increase octane. It would also reduce the need of including more expensive refining products, which the Dominican Republic lacks. The content of reformate is still significant even when a noteworthy amount of ethanol is added to gasoline, which is positive because it is the blendstock produced in a higher share in the country. The reduction of catalytic gasoline, reformate and isomerate when ethanol is added is proportionate.

Figure 145: Optimized blendstock mix for ethanol blends and final composition of ethanol grades



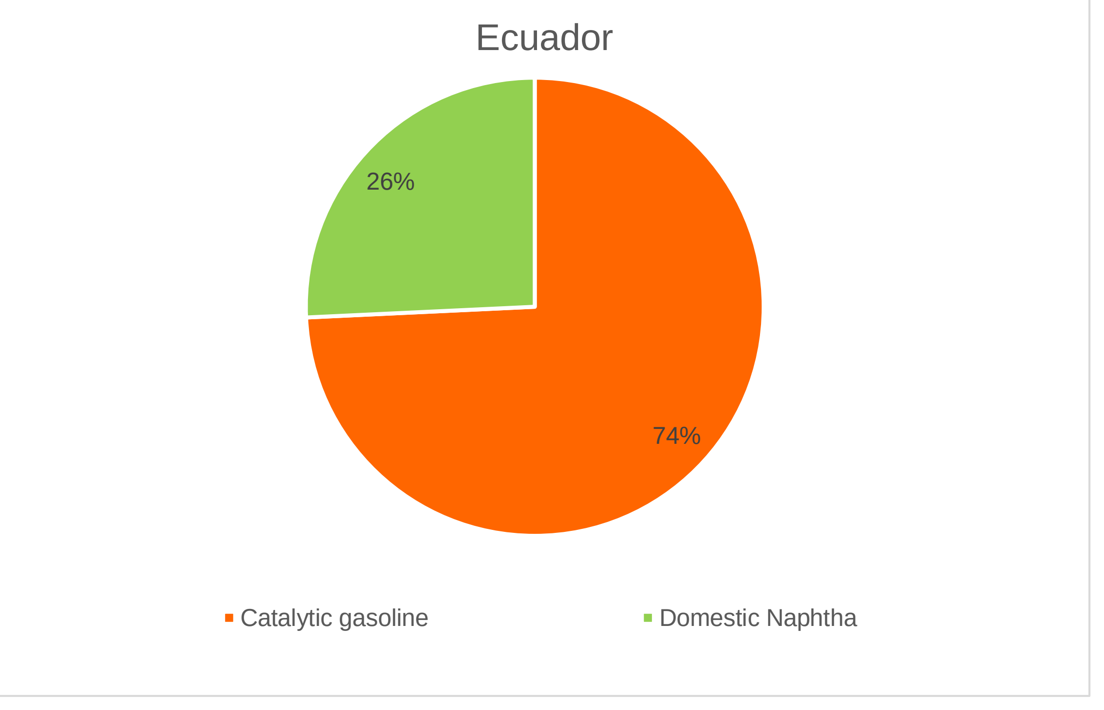
Source: HCX

Ecuador

In Figure 147, the optimized blendstock mix for gasoline production is depicted, as well as the optimized blendstock mix when ethanol is added for the E10, E15, E20, E25 and E30 grades.

This is also compared to the current gasoline blending components mix, as shown below.

Figure 146: Gasoline blending components produced in Ecuador



Source: HCX with Wood Mackenzie PennEnergy Research and Oil and Gas Journal data

The Ecuadorian current gasoline blend (shown here) and the optimized blendstock mix shown below show some of the same components. The model has prioritized the use of domestically produced naphtha and catalytic gasoline provided that quality specifications are met, even though imports of other components may be more economic at times. High octane blendstock is considered Reformate in the blending optimization model. Domestic naphtha is considered to have RON 78, produced by Petroecuador.

The increase of ethanol content in Ecuadorian gasoline would imply the reduction of high octane blendstock, and catalytic gasoline proportionally. Moreover, it would decrease sulfur and hydrocarbons content. Most gasoline consumed in Ecuador is low-octane, and this will need to be addressed particularly when Euro 5 enabling fuel quality standards are implemented, which the country plans to do soon.

Figure 147: Optimized blendstock mix for ethanol blends and final composition of ethanol grades

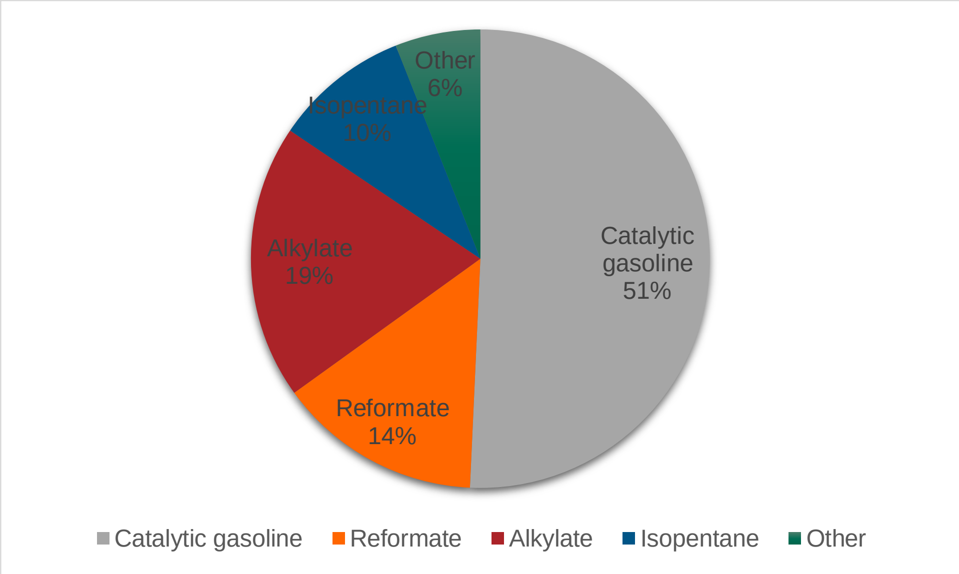
Source: HCX

El Salvador

In Figure 149, the optimized blendstock mix for gasoline production is depicted, as well as the optimized blendstock mix when ethanol is added for the E10, E15, E20, E25 and E30 grades.

This is compared to the gasoline blending components mix, as shown below.

Figure 148: Gasoline blending components produced in El Salvador



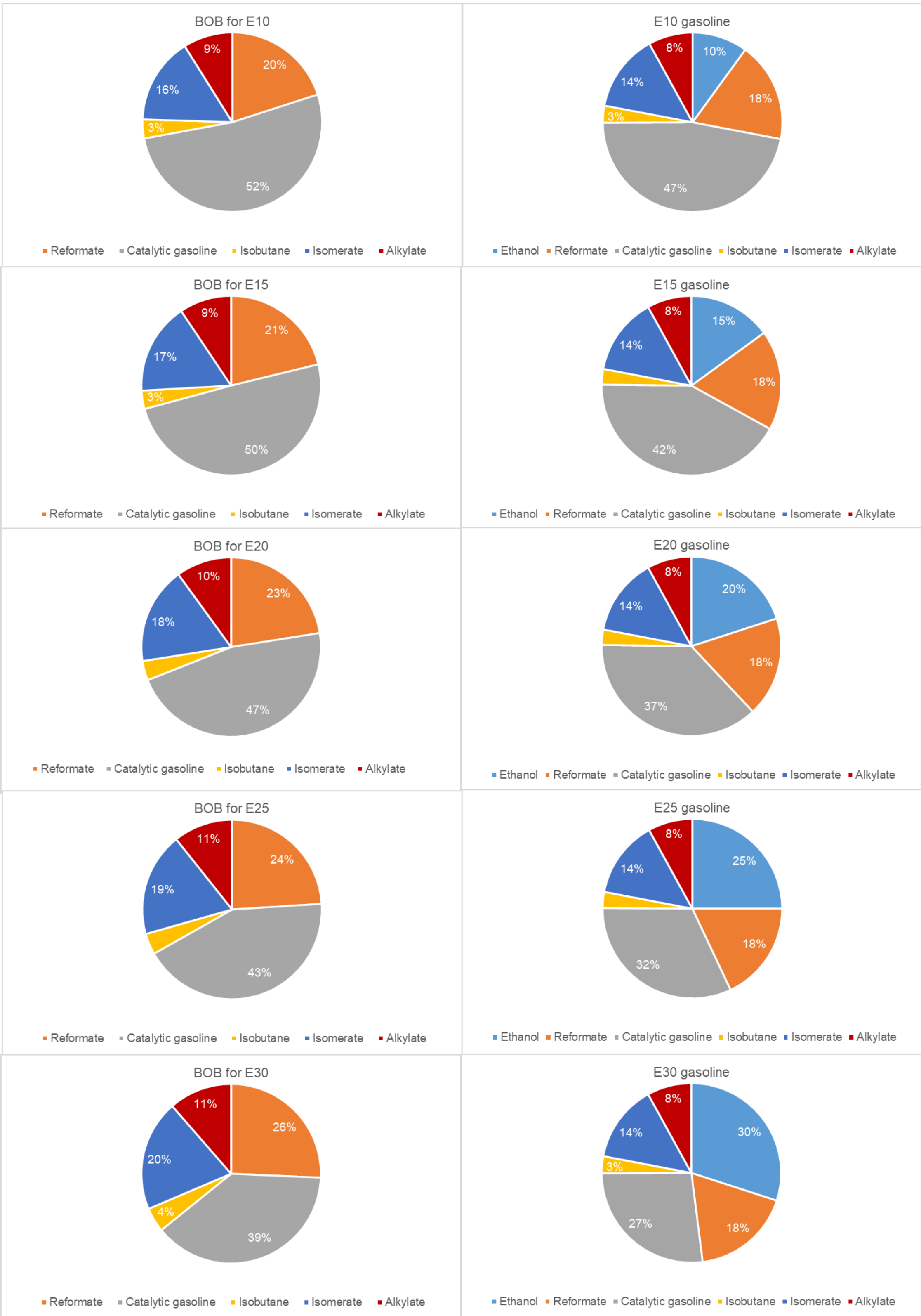
Source: SGS INSPIRE Compilation

The Salvadorian optimized blendstock mix shown below is more complex than the current gasoline blend. As the other Central American countries, gasoline in El Salvador is formed by catalytic gasoline, reformate, and small quantities of isomerate and isobutane.

According to the optimization model, the increase of ethanol content in gasoline from El Salvador would mostly imply the reduction of catalytic gasoline, as shown in other countries in the world. This is due to its price, its availability, and its octane, lower than reformate's. Furthermore, the model reduces alkylates in the optimization mix.

Since gasoline imported by El Salvador comes mostly from the U.S., the addition of 10% v/v should not pose any problem, as this is the blend used more frequently in the U.S.

Figure 149: Optimized blendstock mix for ethanol blends and final composition of ethanol grades



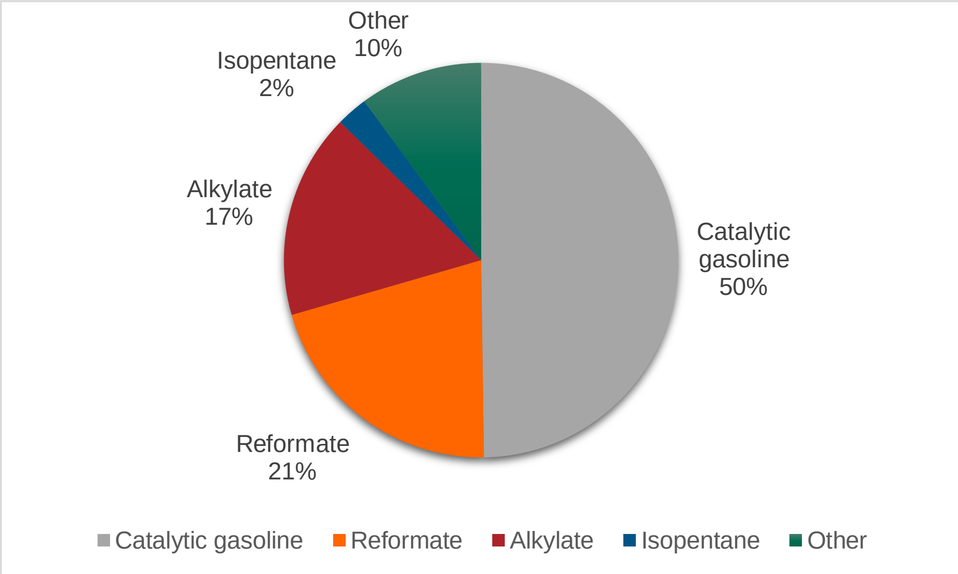
Source: HCX

Guatemala

In Figure 151, the optimized blendstock mix for gasoline production is depicted, as well as the optimized blendstock mix when ethanol is added for the E10, E15, E20, E25 and E30 grades.

This is compared to gasoline blending components mix, as shown below.

Figure 150: Gasoline blending components produced in Guatemala



Source: SGS INSPIRE Compilation

The Guatemalan optimized blendstock mix is more complex than the current gasoline blend. As the other Central American countries, gasoline in El Salvador is formed by catalytic gasoline, reformate, and small quantities of isomerate and isobutane.

According to the optimization model, the increase of ethanol content in gasoline from Guatemala would mostly imply the reduction of catalytic gasoline, as shown in other countries in the world. This is due to its price, its availability, and its octane, lower than reformate's. Furthermore, the model reduces alkylates in the optimization mix.

Since gasoline imported by Guatemala comes mostly from the U.S., the addition of 10% v/v should not pose any problem, as this is the blend used more frequently in the U.S.

Figure 151: Optimized blendstock mix for ethanol blends and final composition of ethanol grades

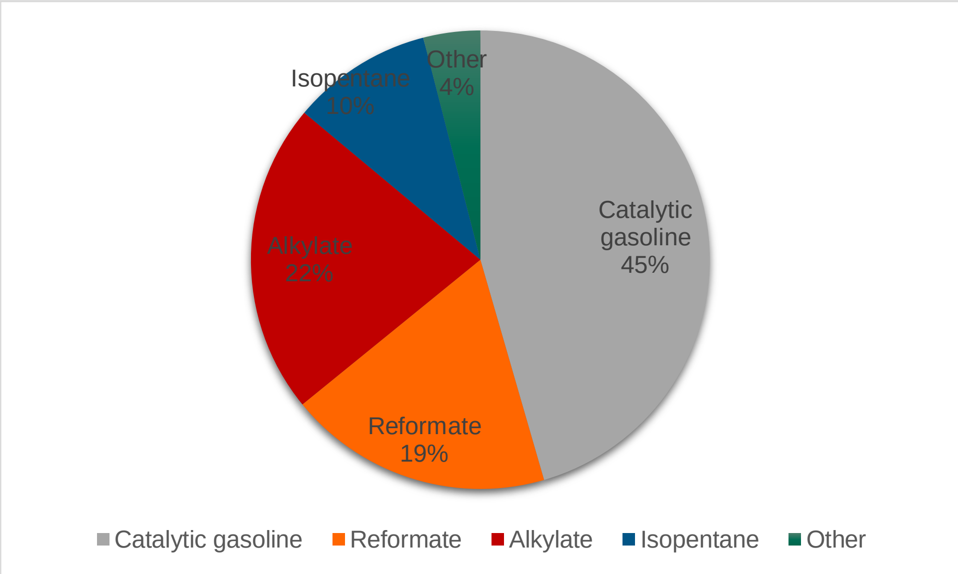
Source: HCX

Honduras

In Figure 153, the optimized blendstock mix for gasoline production is depicted, as well as the optimized blendstock mix when ethanol is added for the E10, E15, E20, E25 and E30 grades.

This is also compared to the gasoline blending components mix, as shown below.

Figure 152: Gasoline blending components produced in Honduras



Source: SGS INSPIRE Compilation

The situation in Honduras is very similar to Guatemala. The Honduras optimized blendstock mix is more complex than the current gasoline blend. As the other Central American countries, gasoline in Honduras is formed by catalytic gasoline, reformate, and small quantities of isomerate and isobutane.

According to the optimization model, the increase of ethanol content in gasoline from Honduras would mostly imply the reduction of catalytic gasoline, as shown in other countries in the world. This is due to its price, its availability, and its octane, lower than reformate's. Furthermore, the model reduces alkylates in the optimization mix.

Since gasoline imported by Honduras comes mostly from the U.S., the addition of 10% v/v should not pose any problem, as this is the blend used more frequently in the U.S.

Figure 153: Optimized blendstock mix for ethanol blends and final composition of ethanol grades

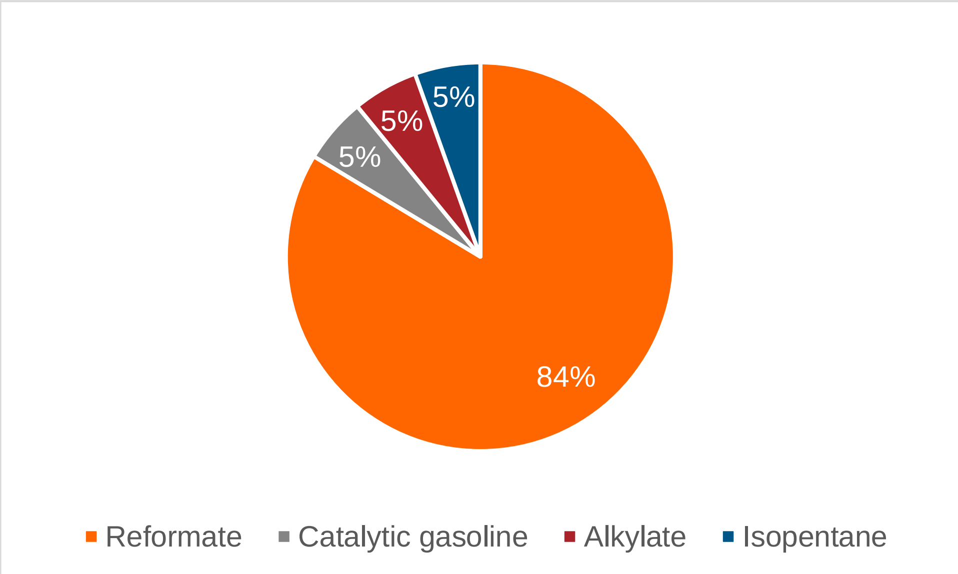
Source: HCX

Jamaica

In Figure 155, the optimized blendstock mix for gasoline production is depicted, as well as the optimized blendstock mix when ethanol is added for the E10, E15, E20, E25 and E30 grades.

This is compared to gasoline blending components mix, as shown below.

Figure 154: Gasoline blending components produced in Jamaica

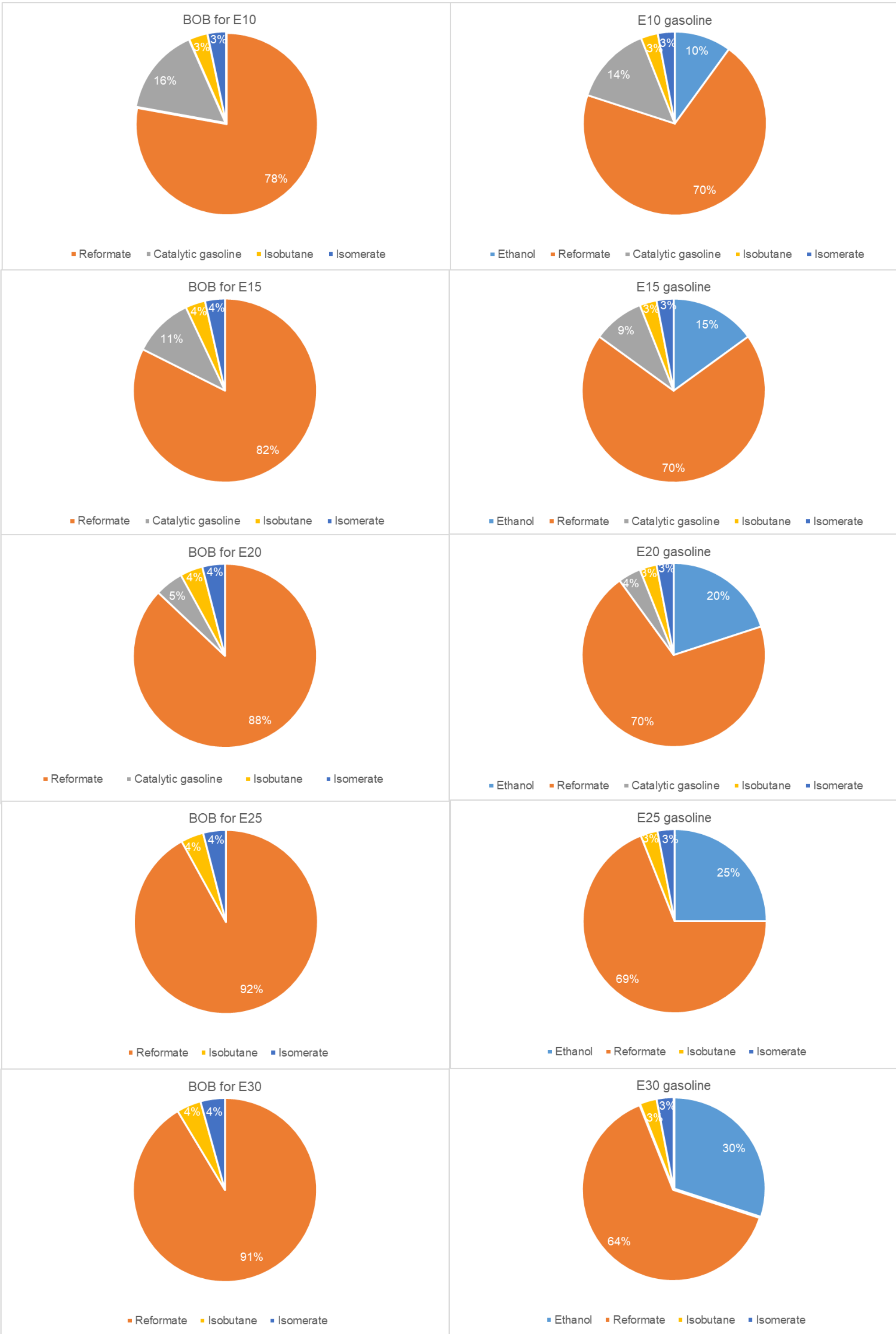


Source: Ministry of Energy, UN Comtrade, EIA, SGS INSPIRE Compilation

The difference of the current blendstock mix for gasoline production with the optimized blend shown below is significant. Currently, mostly reformate is used as blending component in Jamaica, due to the simplicity of its refineries, but to improve fuel quality without increasing the total price of gasoline, small quantities of isobutane and isomerate should be added.

In 2018 the government started planning to increase the ethanol mandate to 15% v/v, but nothing has been confirmed yet. The increase of ethanol content in the blendstock mix can help reduce sulfur and increase octane. It would imply the reduction of reformate and catalytic gasoline, which are the by-products most used in countries with simple refineries. This would mean that Jamaica needs to include high octane compounds, which are produced in more complexed refineries and are usually more expensive.

Figure 155: Optimized blendstock mix for ethanol blends and final composition of ethanol grades



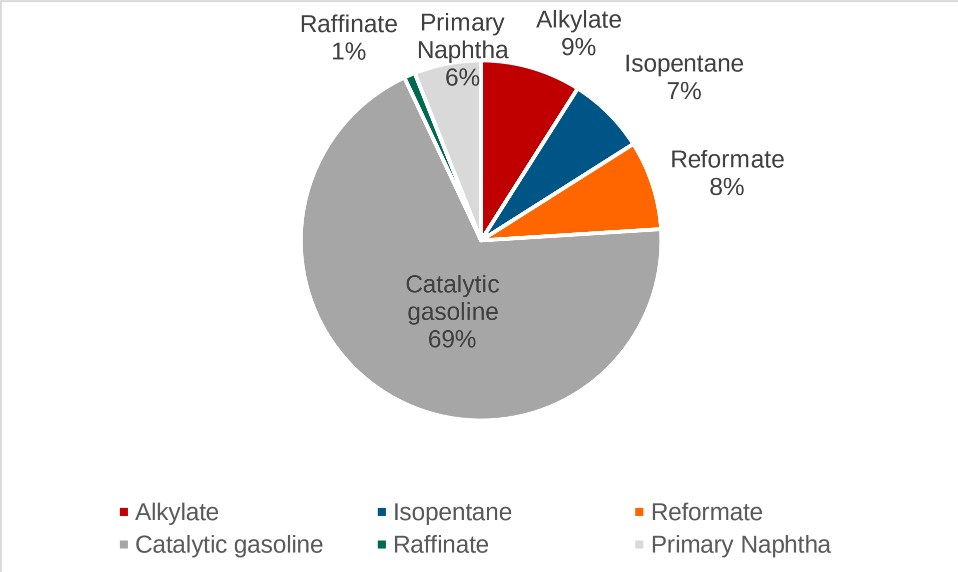
Source: HCX

Mexico

In Figure 157, the optimized blendstock mix for gasoline production is depicted, as well as the optimized blendstock mix when ethanol is added for the E10, E15, E20, E25 and E30 grades.

It is compared to the gasoline blending components mix, as shown below.

Figure 156: Share of gasoline blending components in Mexico



Source: PEMEX, EIA, SGS INSPIRE Compilation

The Mexican current gasoline blendstock mix (shown here) has the similar share of blending components as the optimized blendstock mix shown below.

To improve gasoline quality, the share of primary naphtha could be replaced by other lighter fractions, like isomerate. When ethanol is added, catalytic gasoline is significantly reduced, as well as alkylate, which is a pricy component. The amount of catalytic gasoline is reduced in a higher proportion than reformate because catalytic gasoline has a lower octane. This would help reducing the need to produce catalytic gasoline, which would be favorable considering the current status of the refining industry in Mexico.

Ethanol is mostly found in gasoline in the Northern part of Mexico, while in the Southern part of the country, the majority of gasoline does not contain ethanol. This is mainly due to logistic issues, since most ethanol present in Mexico is from gasoline imported from the U.S. Furthermore, Mexico has complex issues with the distribution of their fuels, and their suffer often from smuggling and sabotages. Therefore, and the fact that the country is reluctant to allow the addition of ethanol into gasoline in the large metropolitan regions, should reduce the area of potential use of ethanol to the Northern part of the country.

Figure 157: Optimized blendstock mix for ethanol blends and final composition of ethanol grades

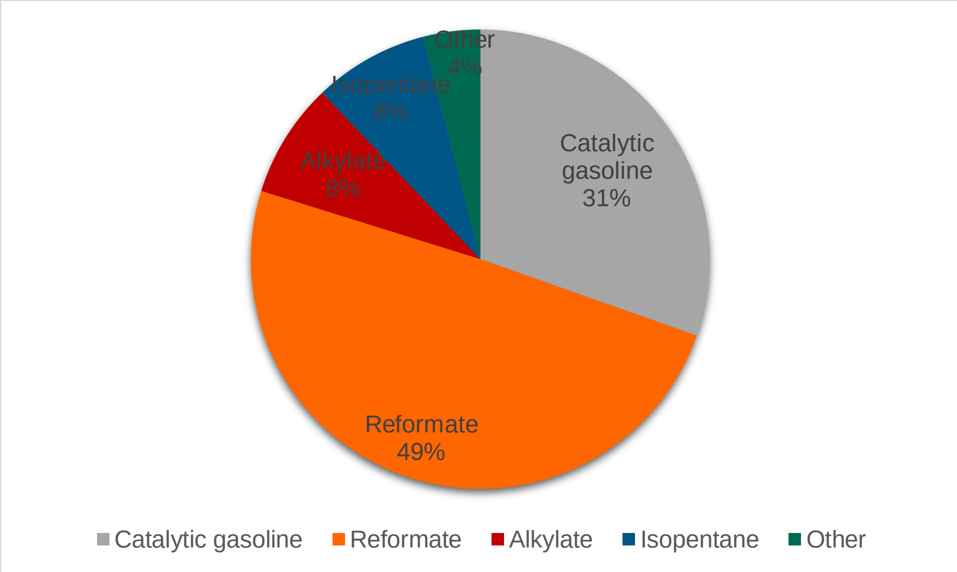
Source: HCX

Nicaragua

In Figure 159, the optimized blendstock mix for gasoline production is depicted, as well as the optimized blendstock mix when ethanol is added for the E10, E15, E20, E25 and E30 grades.

It is compared with gasoline blending components mix as shown below.

Figure 158: Gasoline blending components produced in Nicaragua



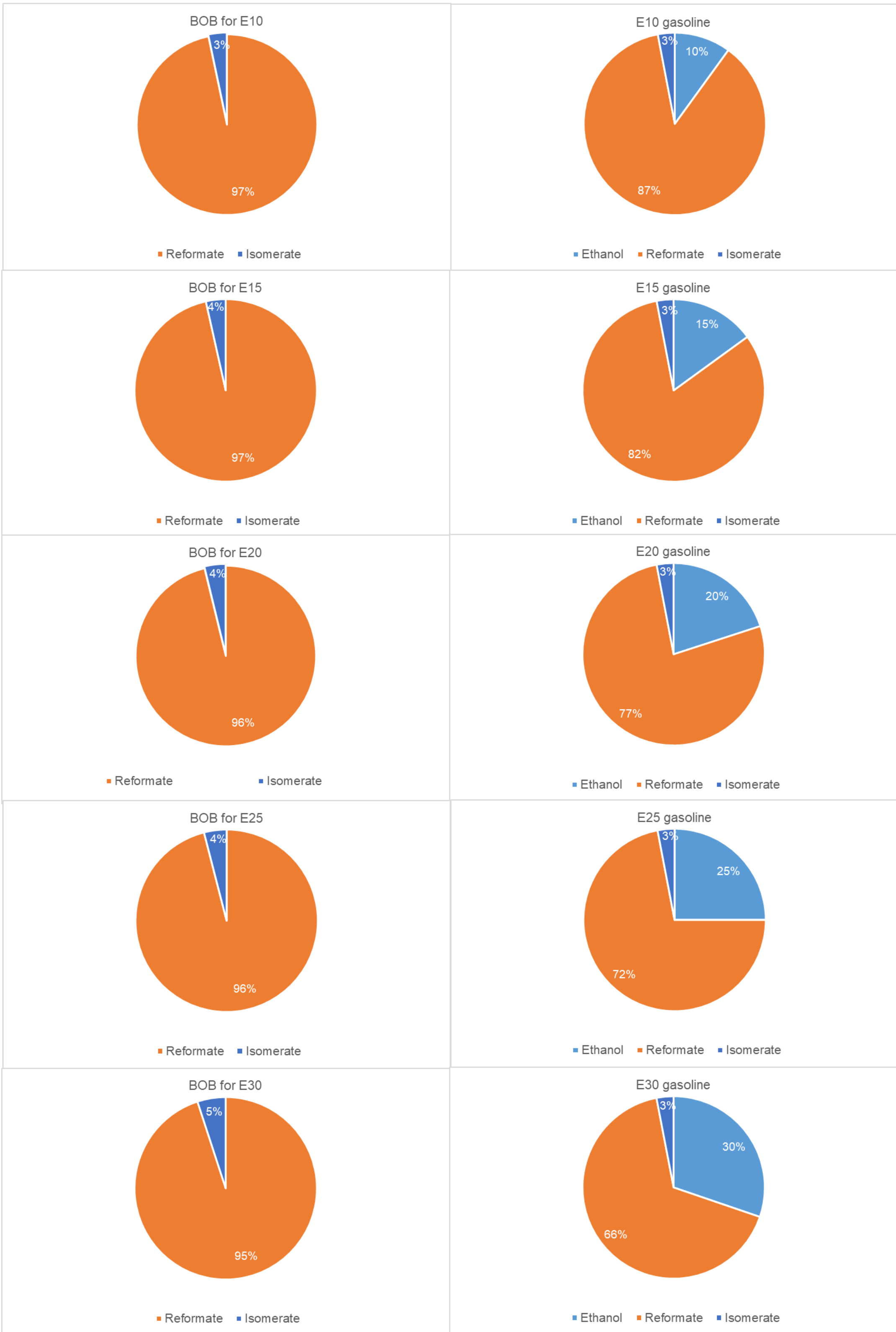
Source: SGS INSPIRE Compilation

The difference of the current blendstock mix for gasoline production (shown here) compared to the optimized mix shown below is significant. However, this is because in the blendstock components mix has been calculated considering gasoline imports. In the mix mostly reformate and catalytic gasoline are the blending components included in gasoline used in Nicaragua, while the optimized mix suggests reformate and small quantities of isomerate, since the refinery mostly produces reformate. The model eliminates alkylates in the optimization mix.

The blendstock average in Nicaragua is simpler than in other Central American countries since the share of U.S. imports is lower than in the neighboring countries and domestic production covers 30% of gasoline demand.

The increase of ethanol content in the blendstock mix can help reduce sulfur and increase octane. It would imply the reduction of reformate as well. This would mean that adding ethanol in gasoline in Nicaragua would help reduce the need to include high octane compounds, which are produced in more complexed refineries and are usually more expensive.

Figure 159: Optimized blendstock mix for ethanol blends and final composition of ethanol grades



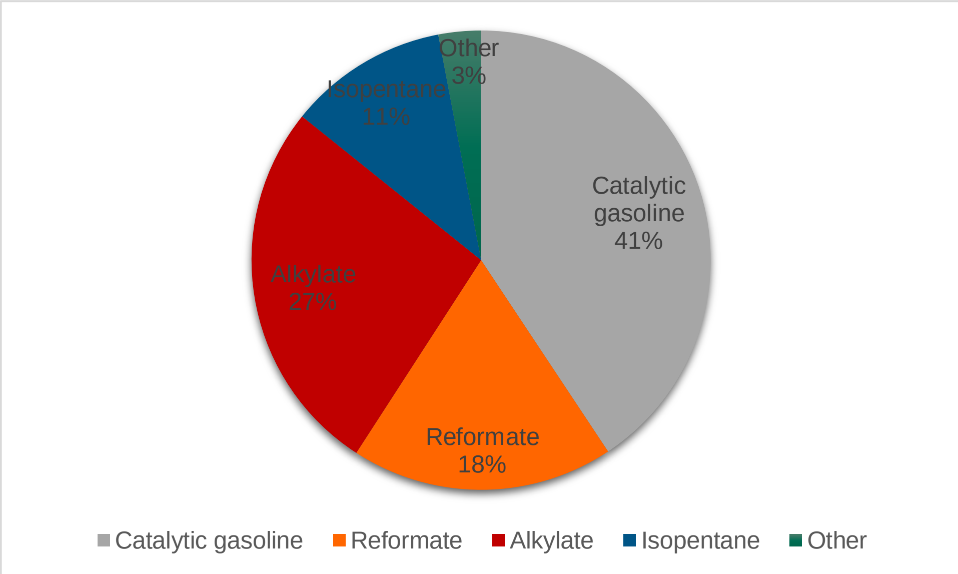
Source: HCX

Panama

In Figure 161, the optimized blendstock mix for gasoline production is depicted, as well as the optimized blendstock mix when ethanol is added for the E10, E15, E20, E25 and E30 grades.

It is compared to gasoline blending components mix as shown below.

Figure 160: Gasoline blending components produced in Panama



Source: SGS INSPIRE Compilation

The situation in Panama is very similar to the other Central American countries that import gasoline from the U.S. As the other Central American countries, gasoline in Panama is formed by catalytic gasoline, reformate, and small quantities of alkylate, isomerate and isobutane.

According to the optimization model, the increase of ethanol content in gasoline from Panama would mostly imply the reduction of catalytic gasoline, as shown in other countries in the world. This is due to its price, its availability, and its octane, lower than reformate's. Furthermore, the model reduces alkylates in the optimization mix.

Since gasoline imported by Panama comes mostly from the U.S., the addition of 10% v/v should not pose any problem, as this is the blend used more frequently in the U.S.

Figure 161: Optimized blendstock mix for ethanol blends and final composition of ethanol grades

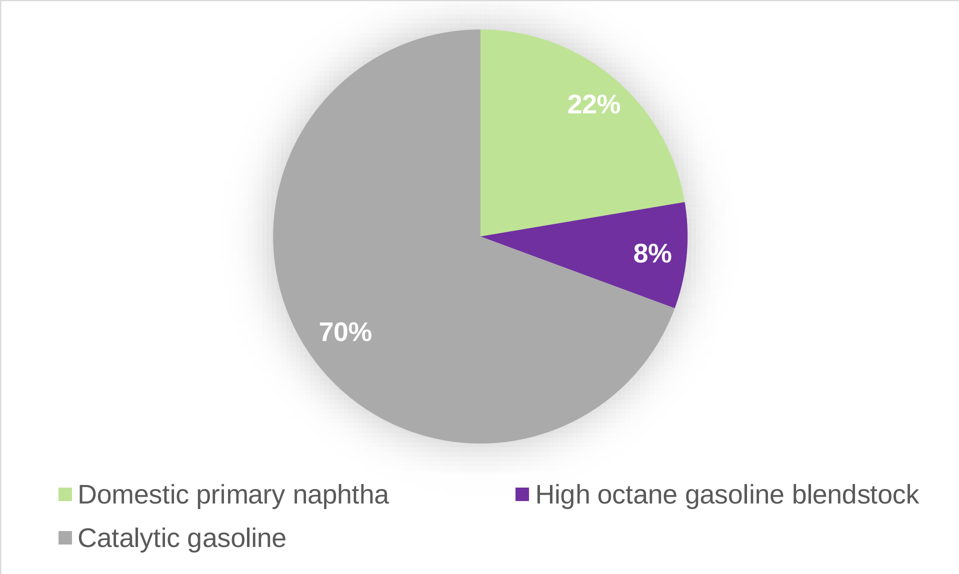
Source: HCX

Peru

In Figure 163, the optimized blendstock mix for gasoline production is depicted, as well as the optimized blendstock mix when ethanol is added for the E10, E15, E20, E25 and E30 grades.

It is compared to the gasoline blending components mix as shown below.

Figure 162: Gasoline blending components in Peru



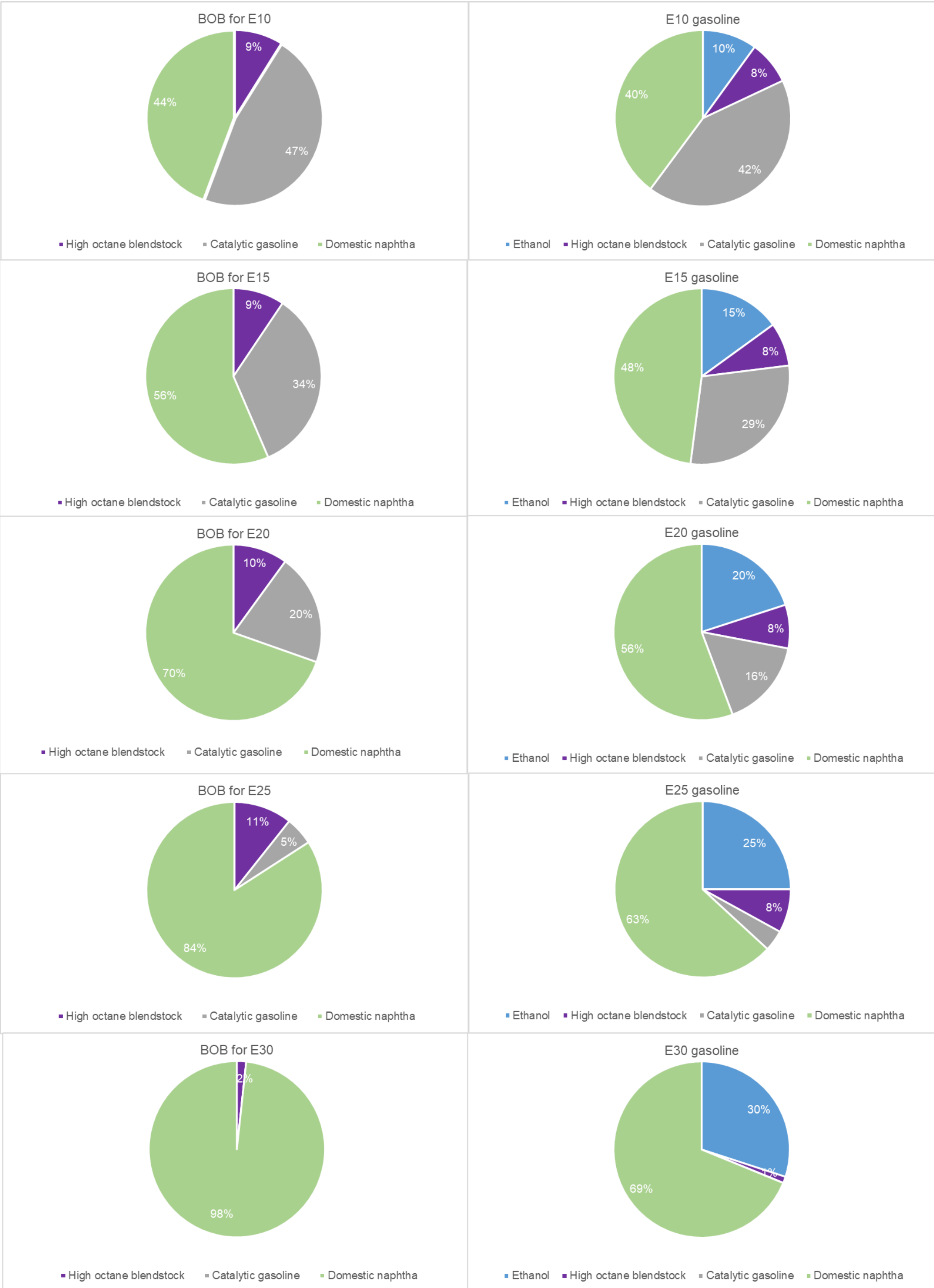
Source: Ministry of Energy and Mines, SGS INSPIRE Compilation

According to the Ministry of Mines and Energy from Peru, there are three main blendstocks in Peruvian gasoline: domestic primary naphtha, catalytic gasoline, and high gasoline blendstock. In the optimized blendstock mix, high octane blendstock is considered reformate, and domestic naphtha is considered to have RON 73. The model has prioritized the use of domestically produced naphtha and catalytic gasoline provided that quality specifications are met, even though imports of other components may be more economic at times.

The addition of ethanol to gasoline may reduce the need of using high octane blendstock and would also reduce the amounts of catalytic gasoline proportionally.

Furthermore, the increase of ethanol content in the blendstock mix can help reduce sulfur and increase octane. Sulfur limits in ethanol blends standards are still very high and do not represent the actual gasoline quality. Octane regulatory limits are still low compared to Euro 6 enabling fuel quality standards. Therefore, a higher share of ethanol in gasoline could help regulators to enact stricter fuel standards.

Figure 163: Optimized blendstock mix for ethanol blends and final composition of ethanol grades



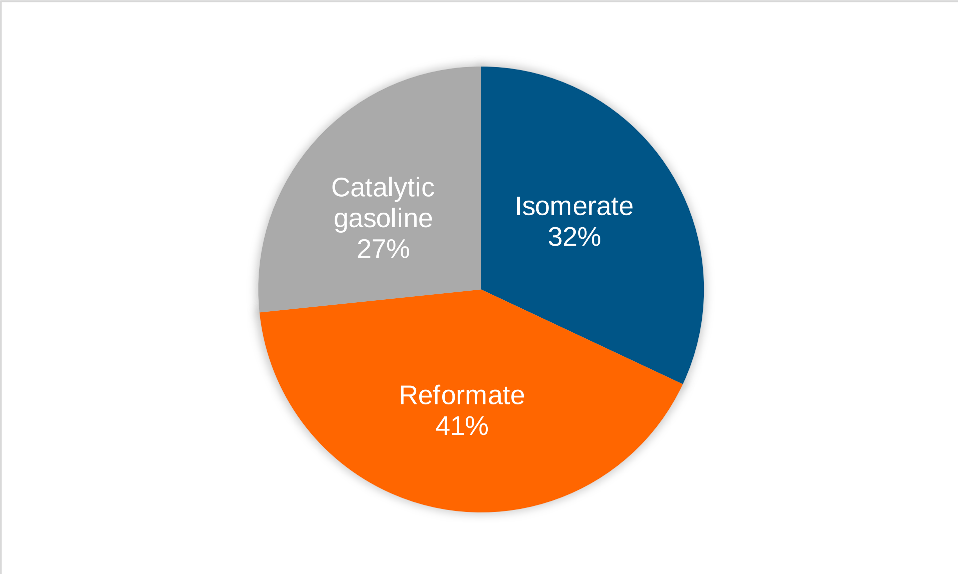
Source: HCX

Uruguay

In Figure 165, the optimized blendstock mix for gasoline production is depicted, as well as the optimized blendstock mix when ethanol is added for the E10, E15, E20, E25 and E30 grades.

It is compared to gasoline blending components mix as shown below.

Figure 164: Gasoline blending components produced in Uruguay

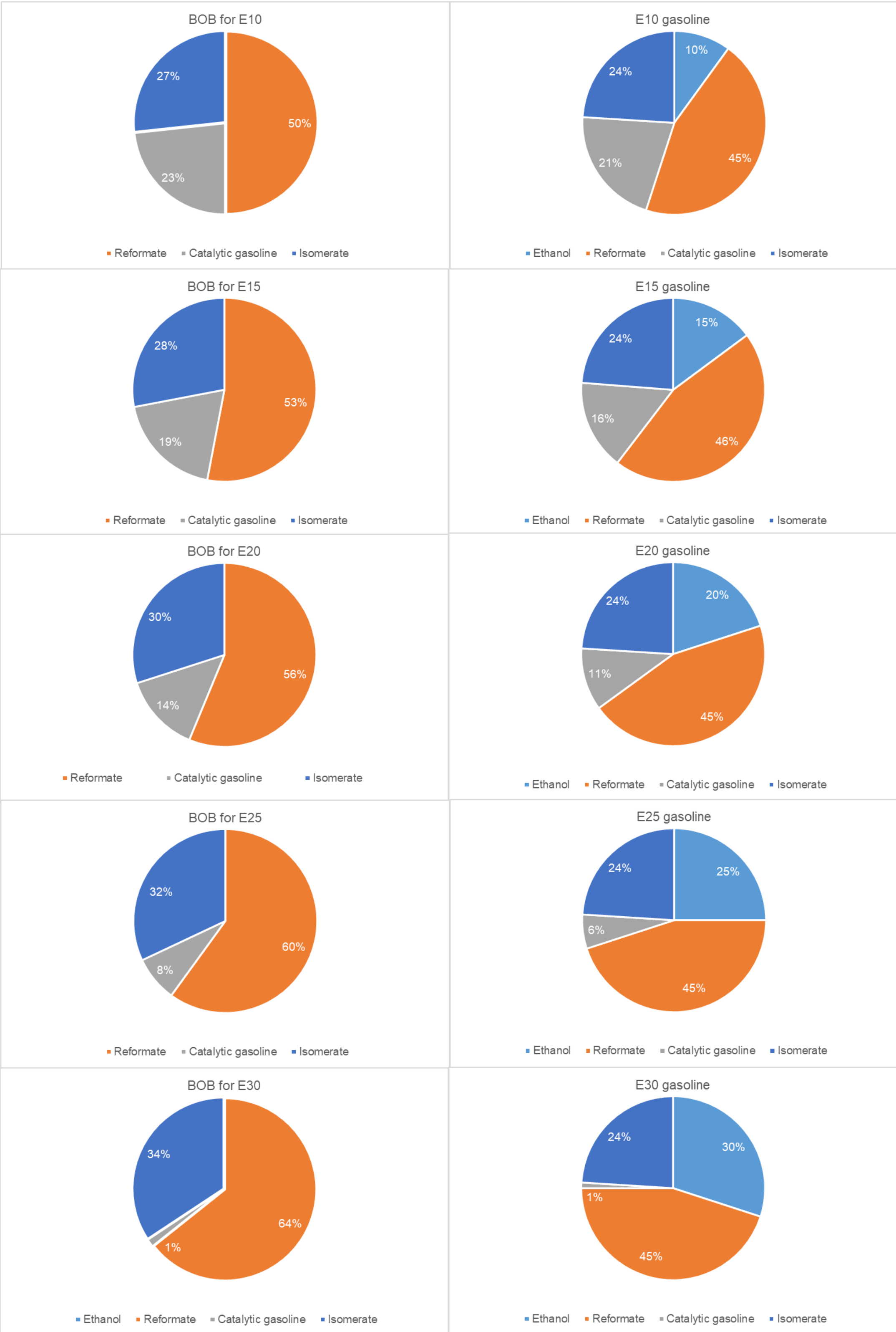


Source: ANCAP, SGS INSPIRE Compilation

According to ANCAP, the national oil company of Uruguay, there are three blendstocks in gasoline: reformate, isomerate and catalytic gasoline, in addition to ethanol. The blend optimization model contemplates a very similar blendstock composition. When ethanol is added, all three components' share decrease, but catalytic gasoline share decreases the most. This is due to its availability, price (similar to isomerate) and octane (higher than reformate's octane).

ANCAP already complies with Euro 5 enabling fuel quality standards, and the increase addition of ethanol would imply the reduction of reformate.

Figure 165: Optimized blendstock mix for ethanol blends and final composition of ethanol grades



Source: HCX

SECTION 3: ANALYSIS OF THE POTENTIAL IMPACT OF ETHANOL BLENDING ON EMISSIONS

SGS INSPIRE has analyzed the potential impact of ethanol blending in gasoline at different levels (10%, 15%, 20%, 25% and 30%) on non-regulated parameters for emissions: carbon monoxide (CO), volatile organic compounds (VOC), evaporative volatile organic compounds (VOC evap), nitrogen oxides (NO_X), sulfur oxides (SO_X), ammonia (NH_3), lead, butadiene, acetaldehydes, formaldehydes, benzene, carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), particulate matter 10 (PM10) and particulate matter 2.5 (PM2.5).

Air pollution is the presence in the air of one or more substances at a concentration or for a duration above their natural levels, with the potential to produce an adverse effect (Seinfeld & Pandis, 2006). Air pollutants and pollutant classes of interest, their major sources, and their evaluation according to the International Agency for Research on Cancer are summarized in Figure 166.

Figure 166: Air pollutants and pollutant classes of interest and their sources

Major air pollutants					
Pollutant/Pollutant class	**Examples**	**Major sources from oil industry**	**IARC carcinogens***	**Relative Potency for cancer risk**	**Ozone precursor**
Photochemical oxidants	Ozone	Generated from NOx, VOCs, and CO	N/A		N/A
Sulfur dioxide (SO_2)	SO_2	Fossil fuel combustion	N/A		
Carbon monoxide (CO)	CO	Fossil fuel combustion, oxidation of biogenic VOC emissions	N/A		Yes
Nitrogen oxides (NO_X)	NO_X	Combustion processes	N/A		Yes
Hazardous air pollutants (HAPs)	Benzene, 1,3-butadiene, formaldehyde, acids	Incomplete combustion, chemical processing, solvent use	Group 1	Benzene: 0.026 1,3-butadiene: 0.155 Formaldehyde: 0.005	
Lead (Pb)	Pb	Leaded fuel combustion, lead processing	Group 2A		
PM, including $PM_{2.5}$, PM_{10}	Inorganic ions (e.g. sulfate); metal oxides; carbonaceous material	Fossil fuel and biomass combustion, biogenic emissions, gas-	N/A		

		to-particle conversion			
Organic carbon (OC)	Hopanes, steranes, polycyclic aromatic hydrocarbons, levoglucosan	Fossil and biomass fuel combustion, oxidation of gaseous organic compounds	N/A		
Secondary air pollutants					
Ammonia (NH_3)	NH_3	Decomposition of organic waste matter, gas exhaust	N/A		
Greenhouse gas emissions	Carbon monoxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and fluorinated gases	Burning of fossil fuels like coal, oil, and natural gas	N/A		Yes
Acetaldehydes	CH_3CHO	It may be formed by the breakdown of ethanol	Group B2	0.002	

* Group 1: carcinogenic to humans
Group 2A: probably carcinogenic to humans
Group 2B: possibly carcinogenic to humans
Group 3: not classifiable as to its carcinogenicity to humans

Source: International Agency for Research on Cancer (IARC), U.S. Environmental Protection Agency (EPA), European Commission, The University of Illinois at Chicago, California Environmental Protection Agency

The model used for this analysis is the International Vehicle Emissions (IVE) model. The model is a computer model (JAVA) designed to estimate emissions from motor vehicles (motorcycles, cars, trucks, buses) with different technology and driving conditions. It estimates the emissions of criteria pollutants, toxic pollutants, and greenhouse gases (GHG) considering exhaust and the evaporative emissions.

The concept of this model was to provide developing countries a rapid emission inventory estimation tool of vehicles in circulation. It should develop emissions' estimates focusing on emission control, predict how different strategies will affect local emissions and measure progress in reducing emissions overtime. It has been used to generate inventories of vehicle emissions in Buenos Aires, Bogotá, Sao Paulo, Lima, Santiago de Chile, Mexico, among others.

It was developed by the University of California at Riverside, the College of Engineering of the Environmental Research and Technology Center, the International Center for Research on Sustainable Systems, and the Research in Sustainable Global Systems Company, with funds from Environmental Protection Agency of the United States (EPA).

The IVE model allows new data files to be created, added, and manipulated within the IVE model or imported from another software. Location and fuel characteristics may be changed directly to adjust the emission rates of the analyzed region. It also incorporates the driving patterns, which allows correcting emissions for local driving habits.

SGS INSPIRE has collected information about vehicle fleets per type of vehicle and fuel in each country. The model uses vehicular technology base emission rates (cars, vans, trucks, buses, motorcycles), average age of the vehicle fleet, average distance drove by type of vehicle per country, as well as geographical and weather conditions (altitude, humidity, temperature).

Emissions Model Methodology

The basis of the emission prediction process of the IVE model is to apply a base emission rate with a series of correction factors to estimate the amount of pollution from a variety of vehicle types. The base emission factor database, as well as the factor adjustments data base are available for download. These factors can be adjusted for the analyzed region, and new data files may be created and manipulated within the IVE Model.

The results for each country included in the study are shown below. Results are depicted by grade, unless grades use the same gasoline blendstock (BOB), which shows the same emissions.

The modelling has been done with SGS Worldwide Fuel Survey data of actual gasoline quality for the countries where this information exists, same data shown in Section 1. For Nicaragua, Dominican Republic and Jamaica, the modelling has been done with current gasoline specifications, because no gasoline actual quality data is available.

Key Takeaways

In most of the countries, emissions of CO, VOC, NO_X, SO_X, NH_3, butadiene, formaldehydes, benzene, CO_2, N_2O, PM2.5 and PM10 decrease with the addition of ethanol. Butadiene emissions do not decrease for some countries, like Bolivia or Chile, but they are very low compared to other countries.

VOC evaporative and CH_4 emissions remain constant with the addition of ethanol for all countries along the report because a correction factor that would reduce emissions with the addition of ethanol in gasoline that could work was not found.

Acetaldehydes emissions increase only after E20, i.e. when 20% v/v ethanol is added to gasoline. With 30% v/v ethanol blended into gasoline, acetaldehydes emissions increase 10% from the baseline or E0 (0% v/v ethanol added). This increase is low compared to the 62% decrease in benzene emissions observed from E30 to E0 in all countries. According to the U.S. Environmental Protection Agency (EPA), acetaldehydes have low acute toxicity from inhalation and moderate acute toxicity from oral or dermal exposure.

The highest emissions of all are CO_2. Emissions of N_2O do not decrease significantly. CO emissions differ in the region. They are high in the countries with old vehicle fleets that do not implement strict vehicle emissions. In Ecuador, benzene emissions are the only ones different between the two octane grades studied.

Analyzing the comparison of emissions from different gasoline grades by octane it is shown that some countries use the same BOB and have the same emissions, like Chile, Colombia or Dominican Republic, other countries use a very similar BOB, like Costa Rica, and other countries use different BOB, it is the case of Argentina. In Argentina, emissions of VOC evap, lead, benzene, CO_2, N_2O, CH_4, PM2.5, PM10 are the same for the two gasoline grades, while emissions of CO, VOC, NO_X, SO_X, NH_3, butadiene, acetaldehydes and formaldehydes decrease when octane increases.

Argentina

The emissions of the non-regulated parameters in kg per day are depicted below.

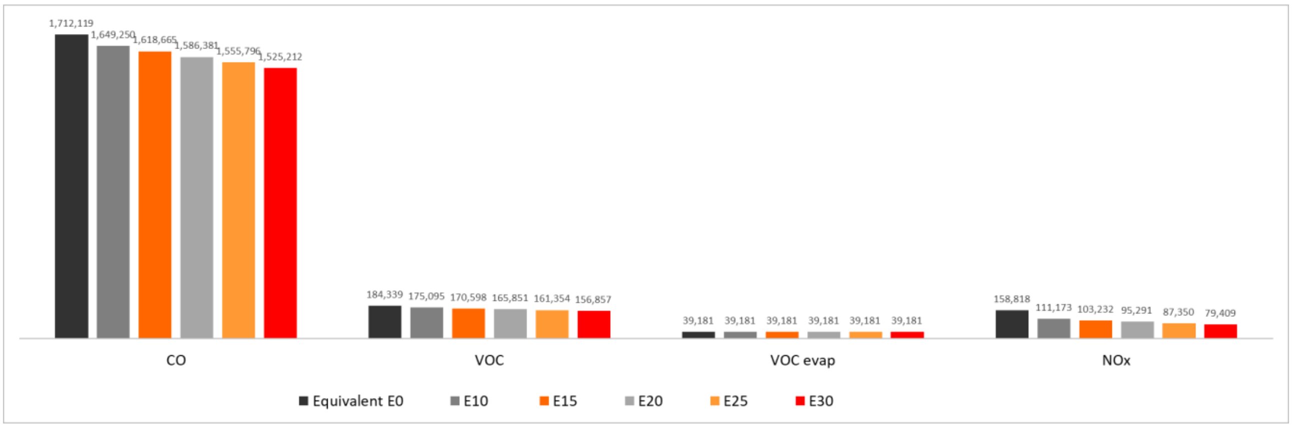
As observed, emissions that decreased with the addition of ethanol for the Argentinean grade 2 and grade 3 are CO, VOC, NO_X, SO_X, NH_3, butadiene, formaldehydes, benzene, CO_2, N_2O, PM2.5 and PM10. Acetaldehydes emissions increased as of E20. The highest emissions of all are from CO_2, and emissions of N_2O do not decrease significantly.

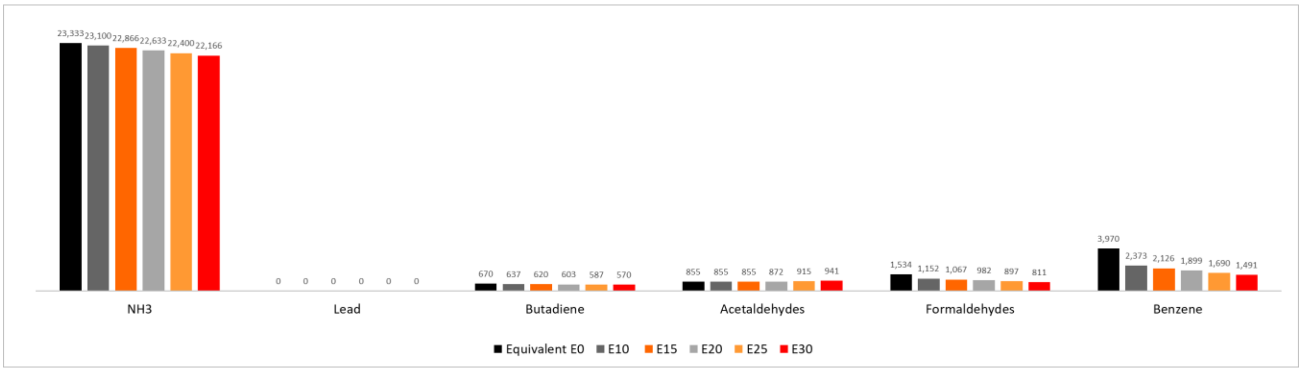
Analyzing the comparison of emissions from gasoline grades RON 93 and RON 97 it is shown that emissions of VOC evap, lead, benzene, CO_2, N_2O, CH_4, PM2.5, PM10 are the same, other emissions decrease with the RON 97 grade.

This indicates that Argentina uses different BOB for the two grades.

Figure 167: Argentina Grade 2: RON 93 - Emissions of non-regulated parameters per ethanol blend

kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	1,712,119	1,649,250	1,618,665	1,586,381	1,555,796	1,525,212
VOC	184,339	175,095	170,598	165,851	161,354	156,857
VOC evap	39,181	39,181	39,181	39,181	39,181	39,181
NOx	158,818	111,173	103,232	95,291	87,350	79,409
SOx	2,757	1,962	1,787	1,613	1,438	1,263
NH3	23,333	23,100	22,866	22,633	22,400	22,166
Lead	0	0	0	0	0	0
Butadiene	670	637	620	603	587	570
Acetaldehydes	855	855	855	872	915	941
Formaldehydes	1,534	1,152	1,067	982	897	811
Benzene	3,970	2,373	2,126	1,899	1,690	1,491
CO2	84,289,513	75,860,562	74,385,495	72,910,429	71,435,363	69,960,296
N2O	2,528	2,528	2,502	2,500	2,490	2,477
CH4	44,764	44,764	44,764	44,764	44,764	44,764
PM 2.5	3,763	3,387	2,897	2,408	1,919	1,430
PM 10	1,090	981	840	698	556	414




23,333 23,100 22,866 22,633 22,400 22,166
0 0 0 0 0 0
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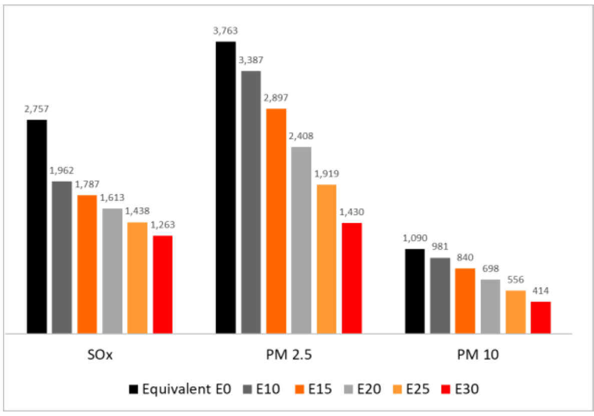
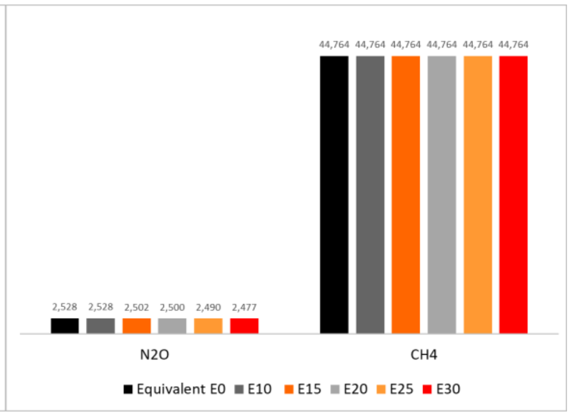
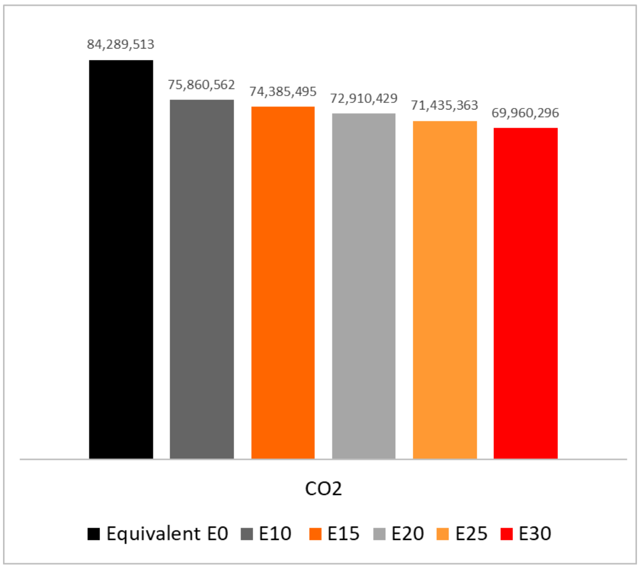
855 855 855 872 915 941
1,534 1,152 1,067 982 897 811
3,970 2,373 2,126 1,899 1,690 1,491
NH3
Lead
Butadiene
Acetaldehydes
Formaldehydes
Benzene
Equivalent E0 E10 E15 E20 E25 E30


2,757 1,962 1,787 1,613 1,438 1,263
3,763 3,387 2,897 2,408 1,919 1,430
1,090 981 840 698 556 414
SOx
PM 2.5
PM 10
Equivalent E0 E10 E15 E20 E25 E30


2,528 2,528 2,502 2,500 2,490 2,477
44,764 44,764 44,764 44,764 44,764 44,764
N2O
CH4
Equivalent E0 E10 E15 E20 E25 E30


84,289,513
75,860,562
74,385,495
72,910,429
71,435,363
69,960,296
CO2
Equivalent E0 E10 E15 E20 E25 E30

Source: HCX

Figure 168: Argentina Grade 3: RON 97 - Emissions of non-regulated parameters per ethanol blend

kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	1,662,878	1,601,809	1,572,100	1,540,741	1,511,032	1,481,322
VOC	177,077	168,196	163,875	159,315	154,994	150,674
VOC evap	39,181	39,181	39,181	39,181	39,181	39,181
NOx	155,620	108,934	101,153	93,372	85,591	77,810
SOx	1,015	722	658	594	529	465
NH3	22,572	22,346	22,120	21,895	21,669	21,443
Lead	0	0	0	0	0	0
Butadiene	624	593	577	561	546	531
Acetaldehydes	796	796	796	812	852	876
Formaldehydes	1,428	1,072	993	914	835	755
Benzene	3,970	2,373	2,126	1,899	1,690	1,491
CO2	84,289,513	75,860,562	74,385,495	72,910,429	71,435,363	69,960,296
N2O	2,123	2,123	2,102	2,100	2,092	2,081
CH4	44,764	44,764	44,764	44,764	44,764	44,764
PM 2.5	3,763	3,387	2,897	2,408	1,919	1,430
PM 10	1,090	981	840	698	556	414

Graphs will not be included here as they are very similar to the graphs obtained from regular gasoline grade 2.

Source: HCX

Bolivia

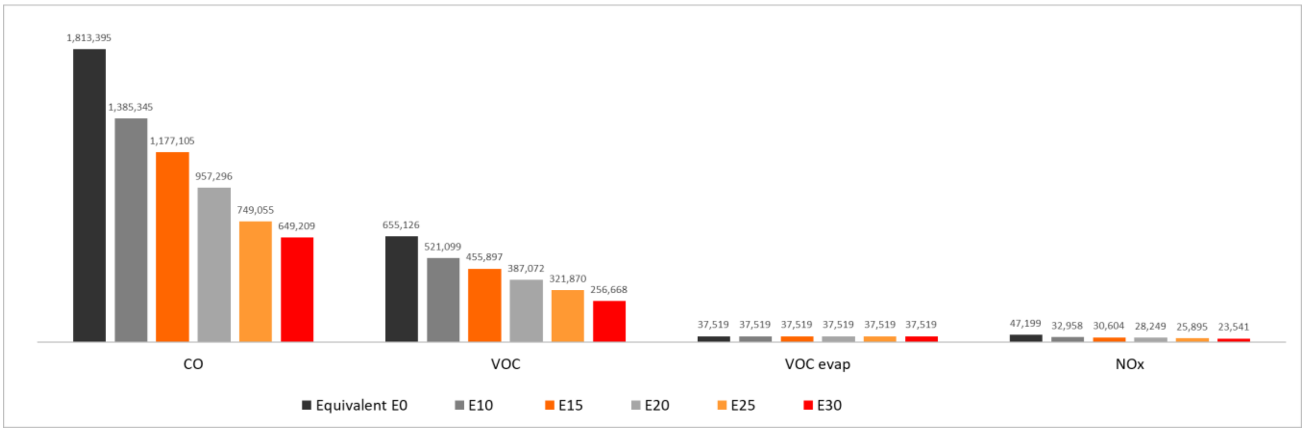
The emissions of the non-regulated parameters in kg per day are depicted below.

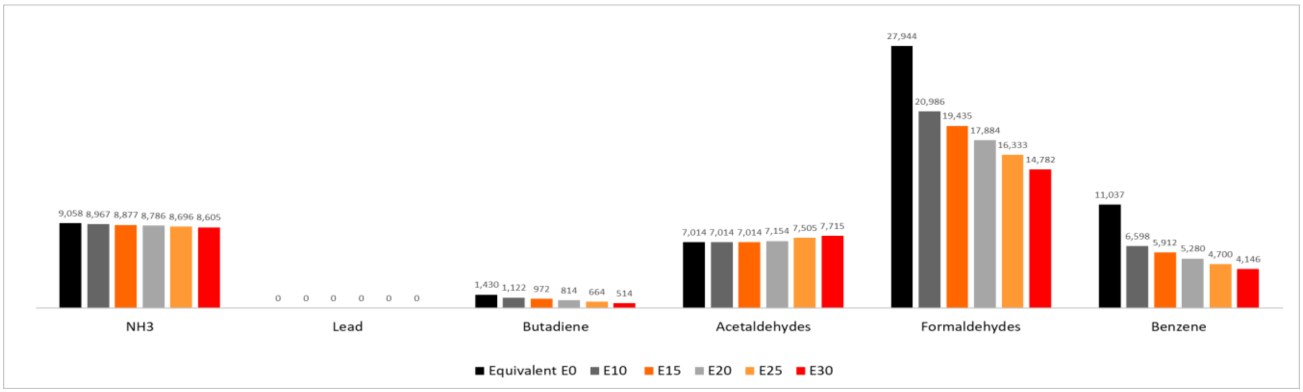
As observed, emissions that decreased with the addition of ethanol for the Bolivian regular and E12 grades are CO, VOC, NO_X, SO_X, NH_3, formaldehydes, benzene, CO_2, N_2O, PM2.5 and PM10. Acetaldehydes emissions increased as of E20.

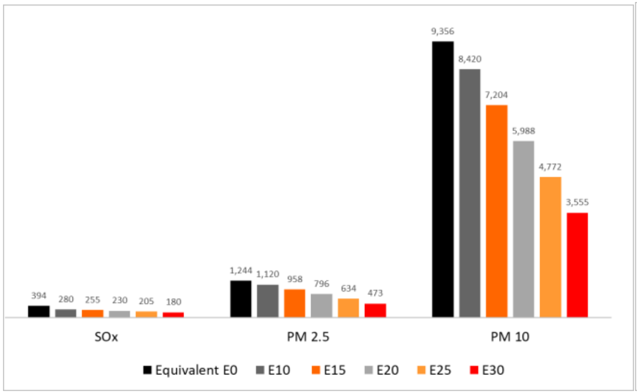
Analyzing the comparison of emissions from the regular and E12 grades it is shown that all emissions are the same, which indicates that they use the same BOB.

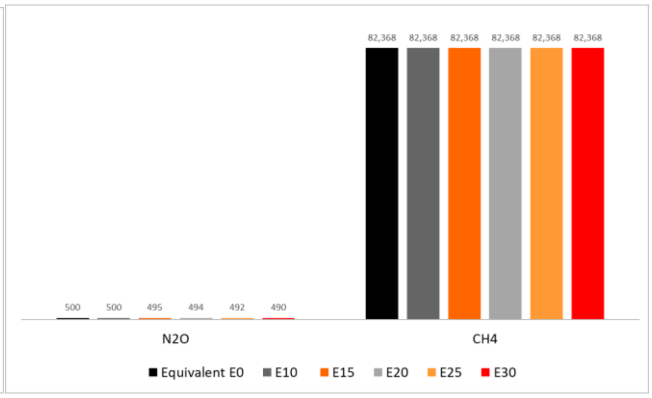
Figure 169: Bolivia Regular RON 85 and E12 - Emissions of non-regulated parameters per ethanol blend

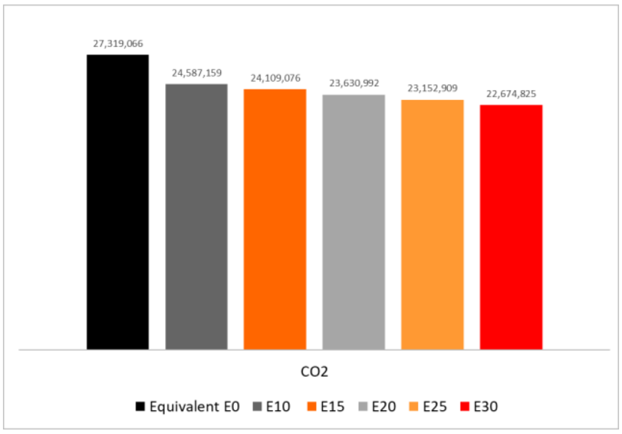
kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	1,813,395	1,385,345	1,177,105	957,296	749,055	649,209
VOC	655,126	521,099	455,897	387,072	321,870	256,668
VOC evap	37,519	37,519	37,519	37,519	37,519	37,519
NOx	47,199	32,958	30,604	28,249	25,895	23,541
SOx	394	280	255	230	205	180
NH3	9,058	8,967	8,877	8,786	8,696	8,605
Lead	0	0	0	0	0	0
Butadiene	1,430	1,122	972	814	664	514
Acetaldehydes	7,014	7,014	7,014	7,154	7,505	7,715
Formaldehydes	27,944	20,986	19,435	17,884	16,333	14,782
Benzene	11,037	6,598	5,912	5,280	4,700	4,146
CO2	27,319,066	24,587,159	24,109,076	23,630,992	23,152,909	22,674,825
N2O	500	500	495	494	492	490
CH4	82,368	82,368	82,368	82,368	82,368	82,368
PM 2.5	1,244	1,120	958	796	634	473
PM 10	9,356	8,420	7,204	5,988	4,772	3,555




9,058 8,967 8,877 8,786 8,696 8,605
NH3
0 0 0 0 0 0
Lead
1,430 1,122 972 814 664 514
Butadiene
7,014 7,014 7,014 7,154 7,505 7,715
Acetaldehydes
27,944 20,986 19,435 17,884 16,333 14,782
Formaldehydes
11,037 6,598 5,912 5,280 4,700 4,146
Benzene
Equivalent E0 E10 E15 E20 E25 E30


394 280 255 230 205 180
SOx
1,244 1,120 958 796 634 473
PM 2.5
9,356 8,420 7,204 5,988 4,772 3,555
PM 10
Equivalent E0 E10 E15 E20 E25 E30


500 500 495 494 492 490
N2O
82,368 82,368 82,368 82,368 82,368 82,368
CH4
Equivalent E0 E10 E15 E20 E25 E30


27,319,066 24,587,159 24,109,076 23,630,992 23,152,909 22,674,825
CO2
Equivalent E0 E10 E15 E20 E25 E30

Source: HCX

Chile

The emissions of the non-regulated parameters in kg per day are depicted below.

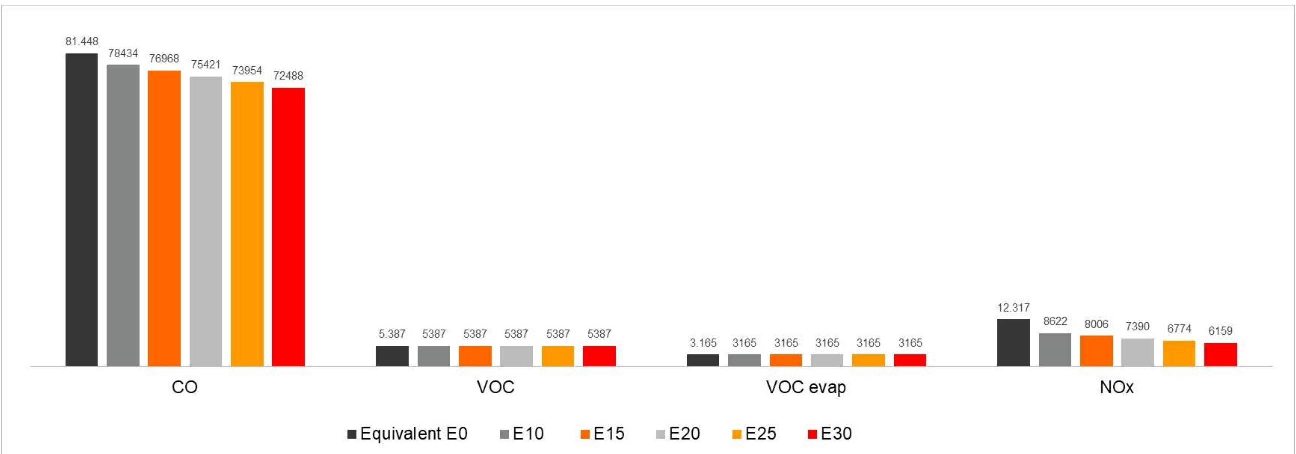
As observed, emissions that decreased with the addition of ethanol for the RON 93, RON 95 and RON 97 grades are CO, NO_X, SO_X, NH_3, formaldehydes, benzene, CO_2, N_2O, PM2.5 and PM10. Acetaldehydes emissions increased as of E20. CO_2 emissions are the highest of all by far.

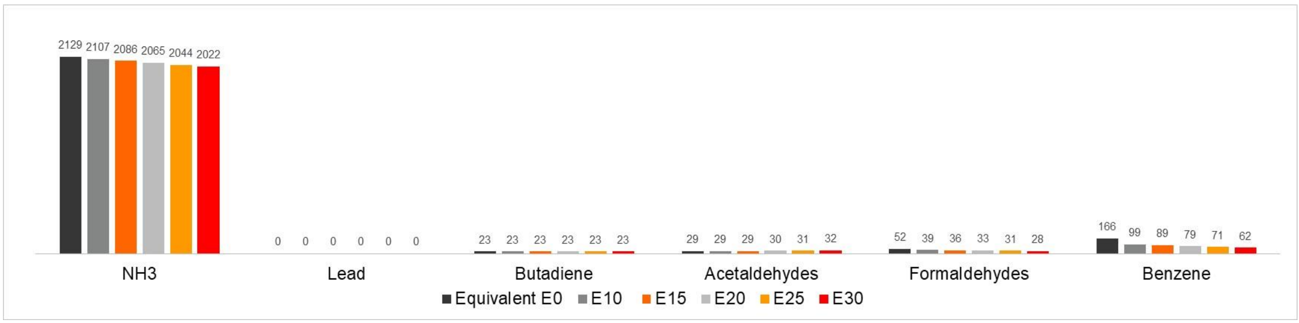
Chile is the only country where VOC emissions do not change when ethanol is added. This is because of the vehicle technology assumed in the model. Vehicles in Chile should meet emissions standards of Euro III to Euro V, and count with an exhaust gas recirculation (EGR) valve. This is why VOC emissions do not change with the addition of ethanol.

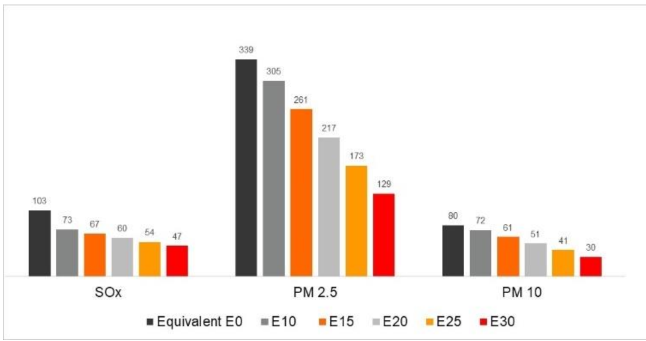
Analyzing the comparison of emissions from the premium and premium plus grades it is shown that all emissions are the same, which indicates that they use the same BOB.

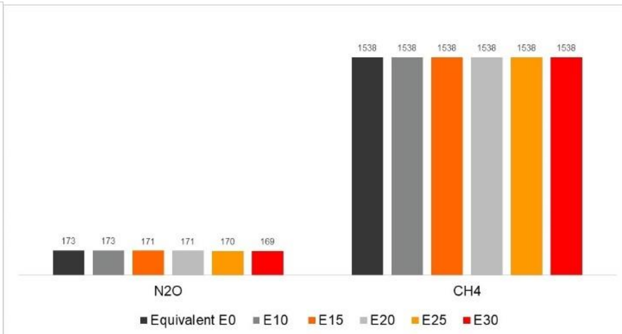
Figure 170: Chile Premium and Premium Plus: RON 93, RON 95, and RON 97 - Emissions of non-regulated parameters per ethanol blend

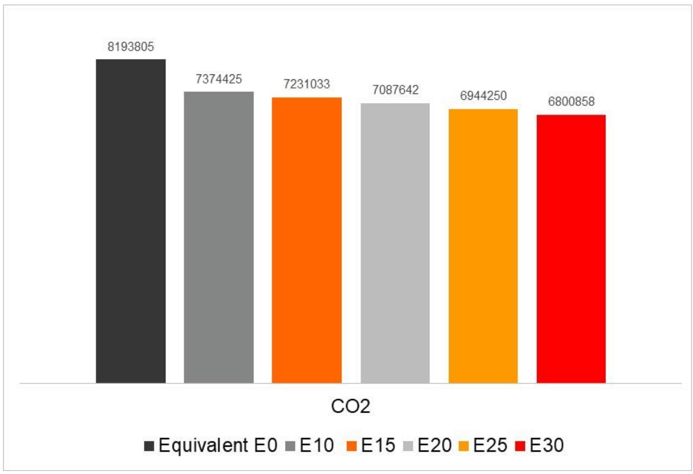
kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	81448	78434	76968	75421	73954	72488
VOC	5387	5387	5387	5387	5387	5387
VOC evap	3165	3165	3165	3165	3165	3165
NOx	12317	8622	8006	7390	6774	6159
SOx	103	73	67	60	54	47
NH3	2129	2107	2086	2065	2044	2022
Lead	0	0	0	0	0	0
Butadiene	23	23	23	23	23	23
Acetaldehydes	29	29	29	30	31	32
Formaldehydes	52	39	36	33	31	28
Benzene	166	99	89	79	71	62
CO2	8193805	7374425	7231033	7087642	6944250	6800858
N2O	173	173	171	171	170	169
CH4	1538	1538	1538	1538	1538	1538
PM 2.5	339	305	261	217	173	129
PM 10	80	72	61	51	41	30




2129 2107 2086 2065 2044 2022
0 0 0 0 0 0
23 23 23 23 23 23
29 29 29 30 31 32
52 39 36 33 31 28
166 99 89 79 71 62
NH3
Lead
Butadiene
Acetaldehydes
Formaldehydes
Benzene
Equivalent E0 E10 E15 E20 E25 E30


103 73 67 60 54 47
339 305 261 217 173 129
80 72 61 51 41 30
SOx
PM 2.5
PM 10
Equivalent E0 E10 E15 E20 E25 E30


173 173 171 171 170 169
1538 1538 1538 1538 1538 1538
N2O
CH4
Equivalent E0 E10 E15 E20 E25 E30


8193805
7374425
7231033
7087642
6944250
6800858
CO2
Equivalent E0 E10 E15 E20 E25 E30

Source: HCX

Colombia

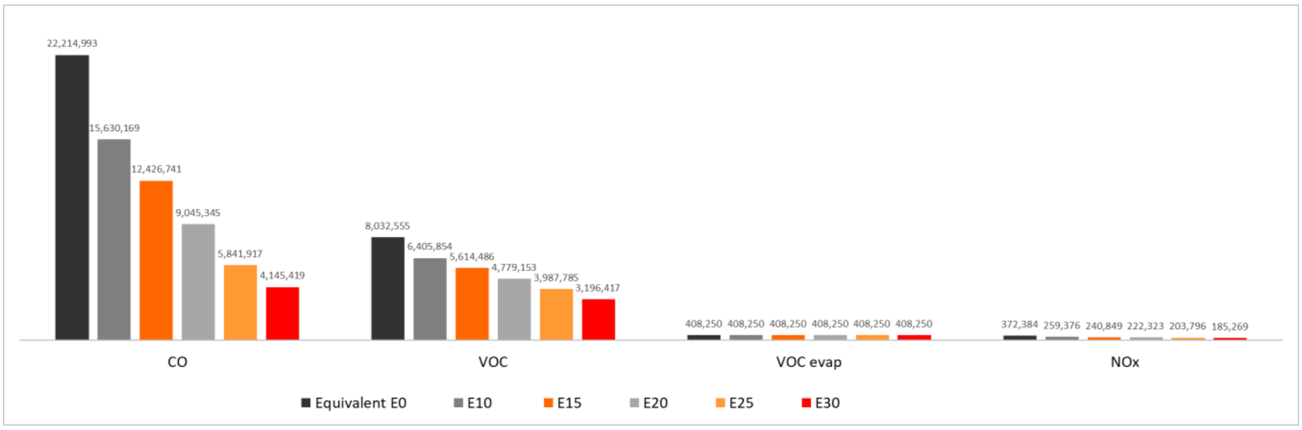
The emissions of the non-regulated parameters in kg per day are depicted below.

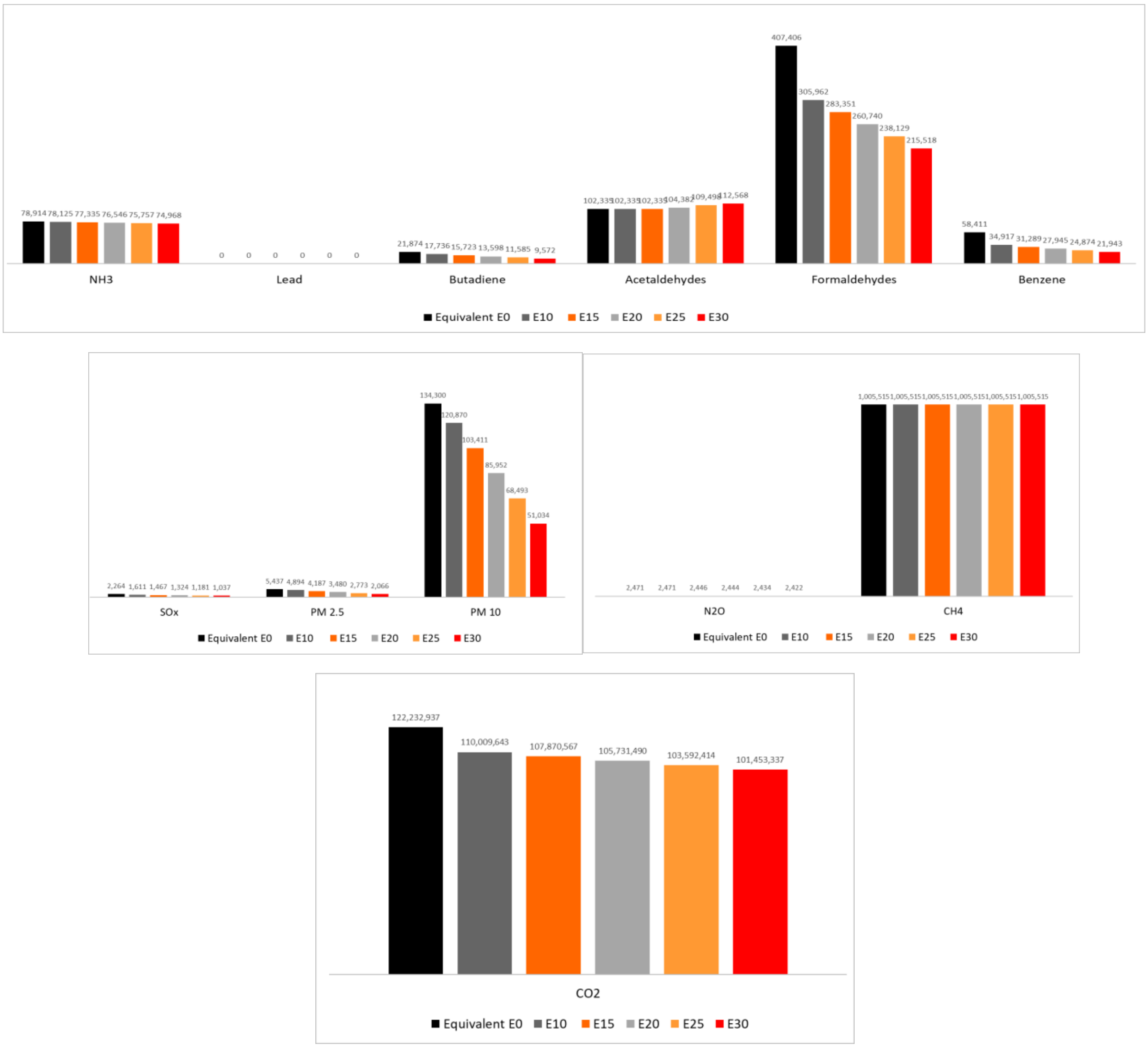
As observed, emissions that decreased with the addition of ethanol for the regular E10 and premium E10 gasoline grades are CO, VOC, NO_X, SO_X, NH_3, butadiene, formaldehydes, benzene, CO_2, N_2O, PM2.5 and PM10. Acetaldehydes emissions increased as of E20. Colombian emissions are higher than in other neighboring countries, due to the vehicle fleet and the current fuel quality. The highest emissions are from CO_2, but CO emissions are also high.

The comparison of emissions from the regular and extra ethanol blend grades shows that all emissions are the same, which indicates that they use the same BOB.

Figure 171: Colombia Gasoline Regular E10: Emissions of non-regulated parameters per ethanol blend

kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	22,214,993	15,630,169	12,426,741	9,045,345	5,841,917	4,145,419
VOC	8,032,555	6,405,854	5,614,486	4,779,153	3,987,785	3,196,417
VOC evap	408,250	408,250	408,250	408,250	408,250	408,250
NOx	372,384	259,376	240,849	222,323	203,796	185,269
SOx	2,264	1,611	1,467	1,324	1,181	1,037
NH3	78,914	78,125	77,335	76,546	75,757	74,968
Lead	0	0	0	0	0	0
Butadiene	21,874	17,736	15,723	13,598	11,585	9,572
Acetaldehydes	102,335	102,335	102,335	104,382	109,498	112,568
Formaldehydes	407,406	305,962	283,351	260,740	238,129	215,518
Benzene	58,411	34,917	31,289	27,945	24,874	21,943
CO2	122,232,937	110,009,643	107,870,567	105,731,490	103,592,414	101,453,337
N2O	2,471	2,471	2,446	2,444	2,434	2,422
CH4	1,005,515	1,005,515	1,005,515	1,005,515	1,005,515	1,005,515
PM 2.5	5,437	4,894	4,187	3,480	2,773	2,066
PM 10	134,300	120,870	103,411	85,952	68,493	51,034




78,914
78,125
77,335
76,546
75,757
74,968
0
0
0
0
0
0
21,874
17,736
15,723
13,598
11,585
9,572
102,339
102,339
102,339
104,382
109,498
112,568
407,406
305,962
283,351
260,740
238,129
215,518
58,411
34,917
31,289
27,945
24,874
21,943
NH3
Lead
Butadiene
Acetaldehydes
Formaldehydes
Benzene
Equivalent E0
E10
E15
E20
E25
E30
2,264
1,611
1,467
1,324
1,181
1,037
5,437
4,894
4,187
3,480
2,773
2,066
134,300
120,870
103,411
85,952
68,493
51,034
SOx
PM 2.5
PM 10
2,471
2,471
2,446
2,444
2,434
2,422
1,005,515
1,005,515
1,005,515
1,005,515
1,005,515
1,005,515
N2O
CH4
122,232,937
110,009,643
107,870,567
105,731,490
103,592,414
101,453,337
CO2

Source: HCX

Figure 172: Colombia Gasoline Premium E10: Emissions of non-regulated parameters per ethanol blend

kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	22,217,447	15,632,486	12,428,991	9,047,525	5,844,030	4,147,466
VOC	8,032,949	6,406,241	5,614,870	4,779,533	3,988,162	3,196,791
VOC evap	408,250	408,250	408,250	408,250	408,250	408,250
NOx	372,612	259,536	240,998	222,460	203,921	185,383
SOx	2,381	1,694	1,543	1,392	1,242	1,091
NH3	78,942	78,152	77,363	76,573	75,784	74,994
Lead	0	0	0	0	0	0
Butadiene	21,876	17,738	15,725	13,600	11,587	9,574
Acetaldehydes	102,337	102,337	102,337	104,384	109,501	112,571
Formaldehydes	407,411	305,965	283,354	260,743	238,132	215,520
Benzene	36,284	21,690	19,437	17,360	15,451	13,631
CO2	122,232,937	110,009,643	107,870,567	105,731,490	103,592,414	101,453,337
N2O	2,494	2,494	2,469	2,467	2,457	2,444
CH4	1,005,515	1,005,515	1,005,515	1,005,515	1,005,515	1,005,515
PM 2.5	5,437	4,894	4,187	3,480	2,773	2,066
PM 10	134,300	120,870	103,411	85,952	68,493	51,034

Graphs will not be included here as they are very similar to the graphs obtained from regular gasoline grade E10.

Source: HCX

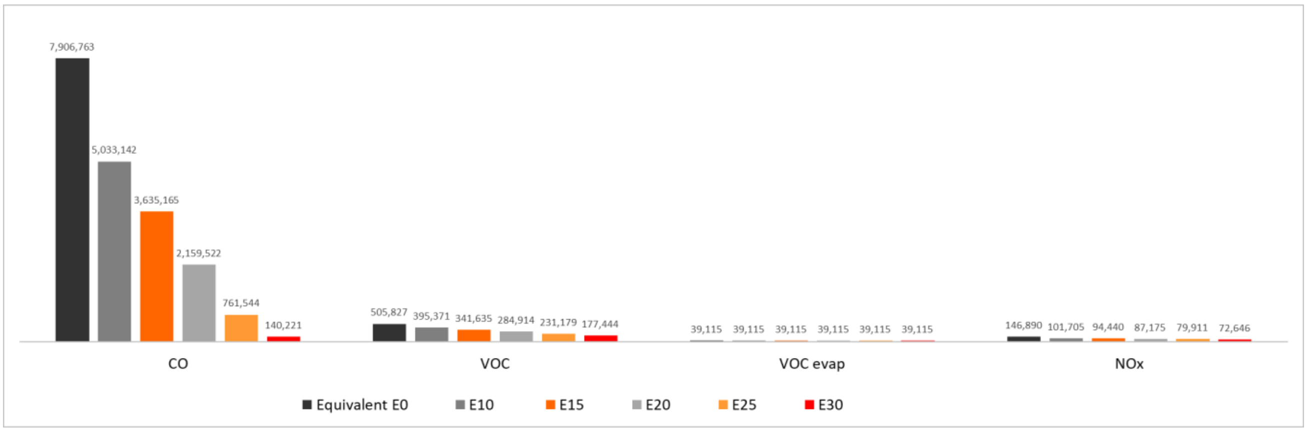
Costa Rica

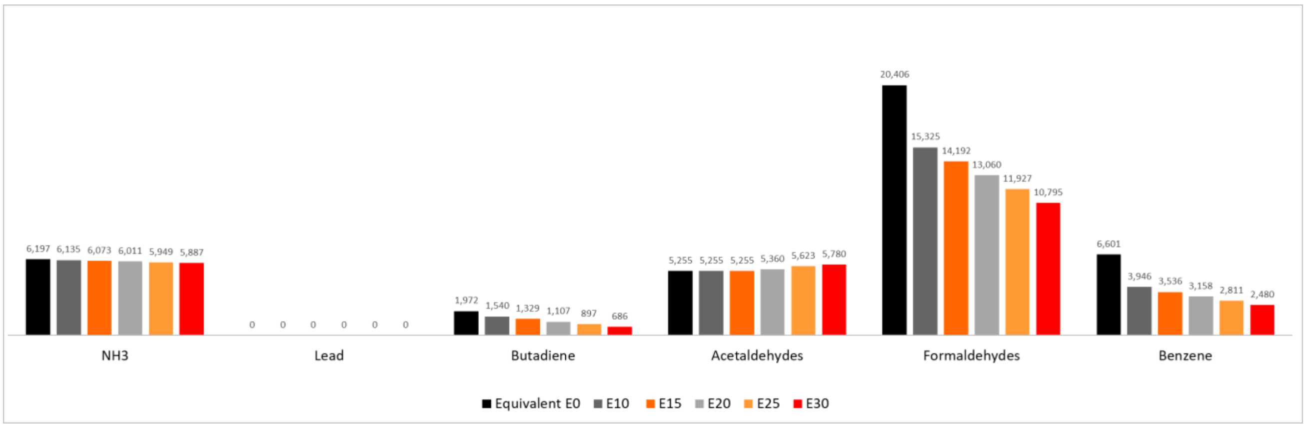
The emissions of the non-regulated parameters in kg per day are depicted below.

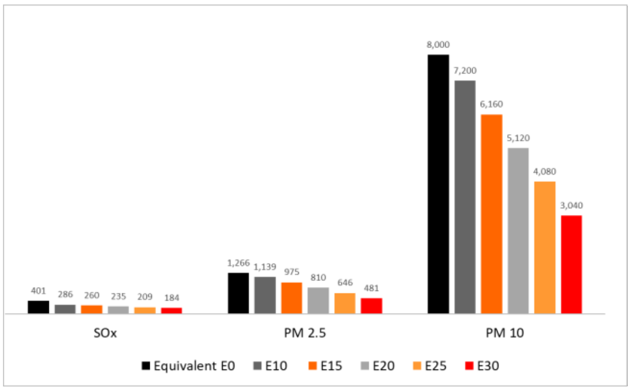
As observed, emissions that decreased with the addition of ethanol for the RON 91 regular grade are CO, VOC, NO_X, SO_X, NH_3, butadiene, formaldehydes, benzene, CO_2, N_2O, PM2.5 and PM10. Acetaldehydes emissions increased as of E20. CO_2 emissions are the highest of all.

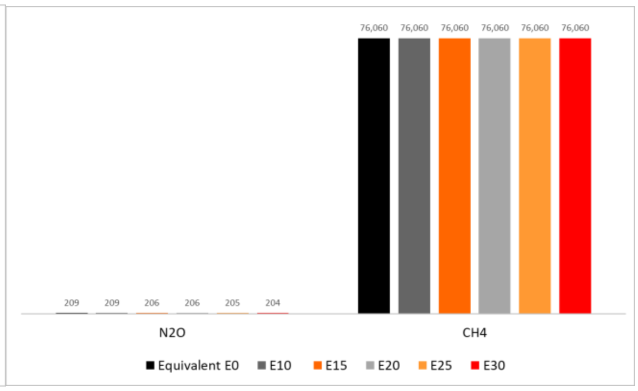
Figure 173: Costa Rica regular grade RON 91: Emissions of non-regulated parameters per ethanol blend

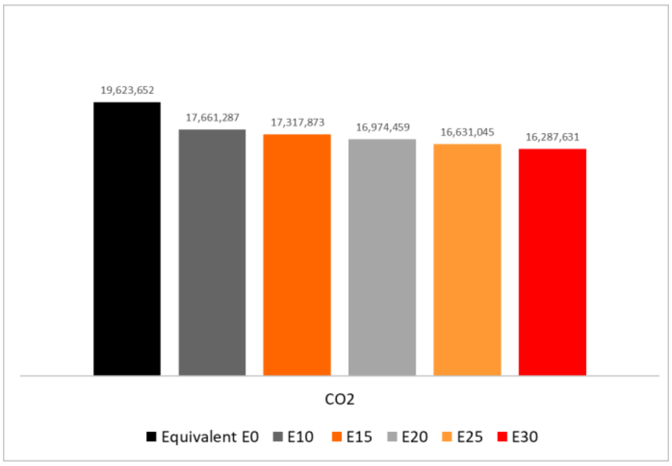
kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	7,906,763	5,033,142	3,635,165	2,159,522	761,544	140,221
VOC	505,827	395,371	341,635	284,914	231,179	177,444
VOC evap	39,115	39,115	39,115	39,115	39,115	39,115
NOx	146,890	101,705	94,440	87,175	79,911	72,646
SOx	401	286	260	235	209	184
NH3	6,197	6,135	6,073	6,011	5,949	5,887
Lead	0	0	0	0	0	0
Butadiene	1,972	1,540	1,329	1,107	897	686
Acetaldehydes	5,255	5,255	5,255	5,360	5,623	5,780
Formaldehydes	20,406	15,325	14,192	13,060	11,927	10,795
Benzene	6,601	3,946	3,536	3,158	2,811	2,480
CO2	19,623,652	17,661,287	17,317,873	16,974,459	16,631,045	16,287,631
N2O	209	209	206	206	205	204
CH4	76,060	76,060	76,060	76,060	76,060	76,060
PM 2.5	1,266	1,139	975	810	646	481
PM 10	8,000	7,200	6,160	5,120	4,080	3,040











Source: HCX

Figure 174: Costa Rica premium grade RON 95: Emissions of non-regulated parameters per ethanol blend

kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	7,906,500	5,032,880	3,634,902	2,159,259	761,282	139,958
VOC	505,810	395,354	341,618	284,898	231,162	177,427
VOC evap	39,115	39,115	39,115	39,115	39,115	39,115
NOx	146,830	101,663	94,401	87,139	79,878	72,616
SOx	367	261	238	214	191	168
NH3	6,191	6,129	6,067	6,005	5,943	5,881
Lead	0	0	0	0	0	0
Butadiene	1,972	1,540	1,329	1,107	897	686
Acetaldehydes	5,255	5,255	5,255	5,360	5,622	5,780
Formaldehydes	20,405	15,324	14,192	13,059	11,927	10,794
Benzene	5,400	3,228	2,892	2,583	2,299	2,029
CO2	19,623,652	17,661,287	17,317,873	16,974,459	16,631,045	16,287,631
N2O	207	207	205	205	204	203
CH4	76,060	76,060	76,060	76,060	76,060	76,060
PM 2.5	1,266	1,139	975	810	646	481
PM 10	8,000	7,200	6,160	5,120	4,080	3,040

Analyzing the comparison of emissions from the regular and premium grades it is shown that all emissions are very similar, which indicates that they use a very similar BOB.

Graphs will not be included here as they are very similar to the graphs obtained from regular gasoline grade.

Source: HCX

Dominican Republic

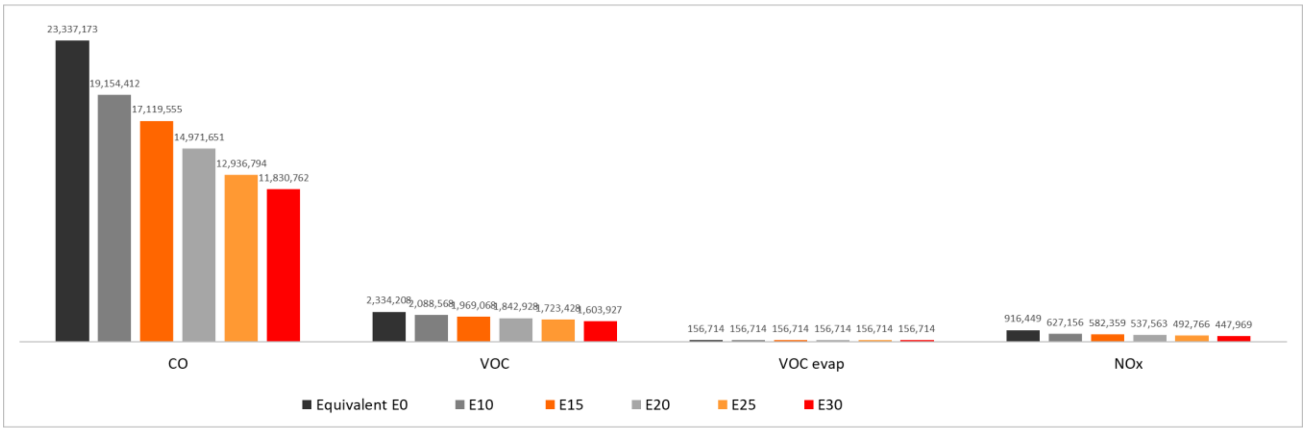
The emissions of the non-regulated parameters in kg per day are depicted below.

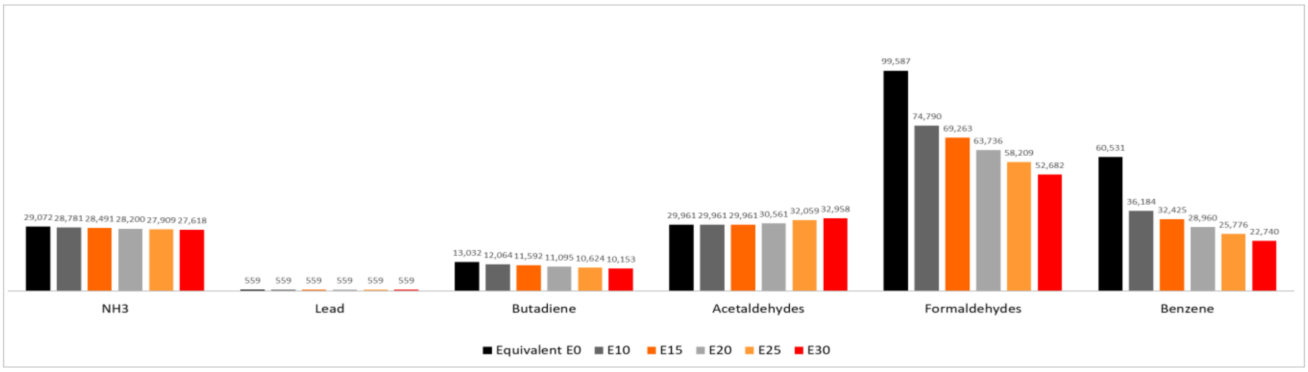
As observed, emissions that decreased with the addition of ethanol for the RON 89 regular and RON 96 premium grades are CO, VOC, NO_X, SO_X, NH_3, butadiene, formaldehydes, benzene, CO_2, N_2O, PM2.5 and PM10. Acetaldehydes emissions increased as of E20. CO_2 and CO emissions are very high, but also VOC emissions.

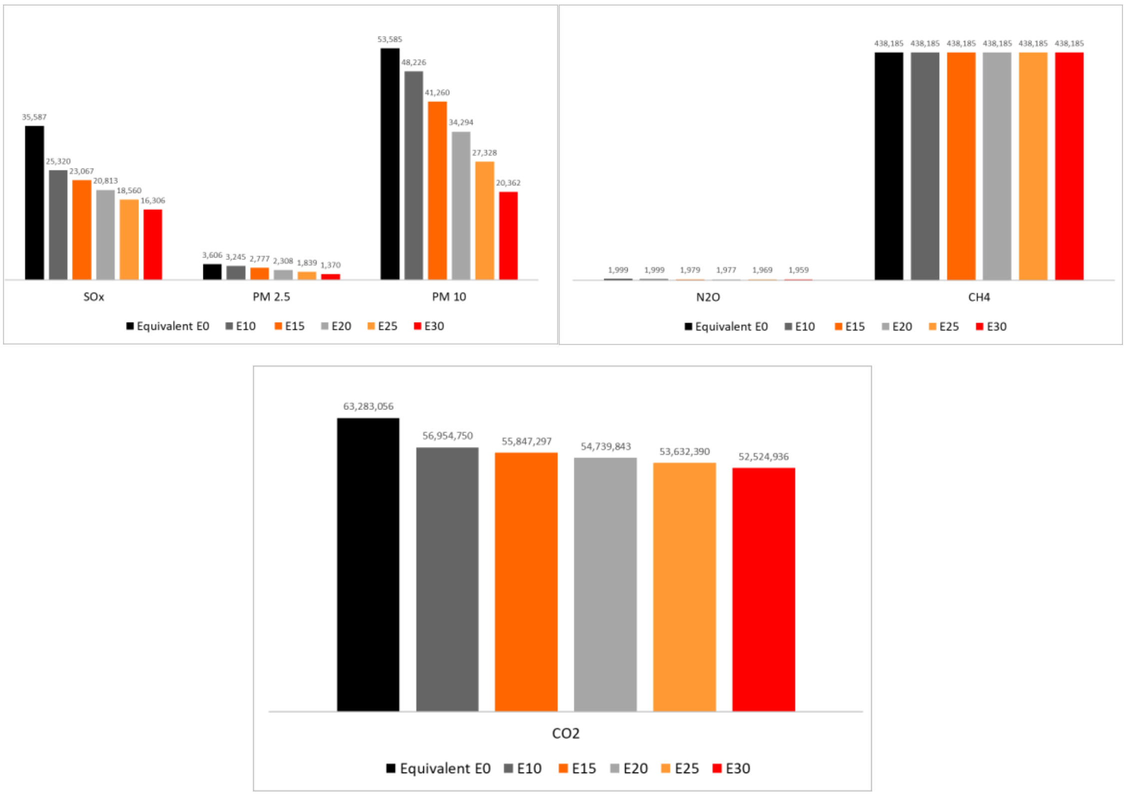
Analyzing the comparison of emissions from the regular and premium grades it is shown that all emissions are the same, which indicates that they use the same BOB.

Figure 175: Dominican Republic Regular and Premium: Emissions of non-regulated parameters per ethanol blend

kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	23,337,173	19,154,412	17,119,555	14,971,651	12,936,794	11,830,762
VOC	2,334,208	2,088,568	1,969,068	1,842,928	1,723,428	1,603,927
VOC evap	156,714	156,714	156,714	156,714	156,714	156,714
NOx	916,449	627,156	582,359	537,563	492,766	447,969
SOx	35,587	25,320	23,067	20,813	18,560	16,306
NH3	29,072	28,781	28,491	28,200	27,909	27,618
Lead	559	559	559	559	559	559
Butadiene	13,032	12,064	11,592	11,095	10,624	10,153
Acetaldehydes	29,961	29,961	29,961	30,561	32,059	32,958
Formaldehydes	99,587	74,790	69,263	63,736	58,209	52,682
Benzene	60,531	36,184	32,425	28,960	25,776	22,740
CO2	63,283,056	56,954,750	55,847,297	54,739,843	53,632,390	52,524,936
N2O	1,999	1,999	1,979	1,977	1,969	1,959
CH4	438,185	438,185	438,185	438,185	438,185	438,185
PM 2.5	3,606	3,245	2,777	2,308	1,839	1,370
PM 10	53,585	48,226	41,260	34,294	27,328	20,362






35,587
25,320
23,067
20,813
18,560
16,306
3,606
3,245
2,777
2,308
1,839
1,370
53,585
48,226
41,260
34,294
27,328
20,362
SOx
PM 2.5
PM 10
Equivalent E0
E10
E15
E20
E25
E30
1,999
1,999
1,979
1,977
1,969
1,959
438,185
438,185
438,185
438,185
438,185
438,185
N2O
CH4
Equivalent E0
E10
E15
E20
E25
E30
63,283,056
56,954,750
55,847,297
54,739,843
53,632,390
52,524,936
CO2
Equivalent E0
E10
E15
E20
E25
E30

Source: HCX

Ecuador

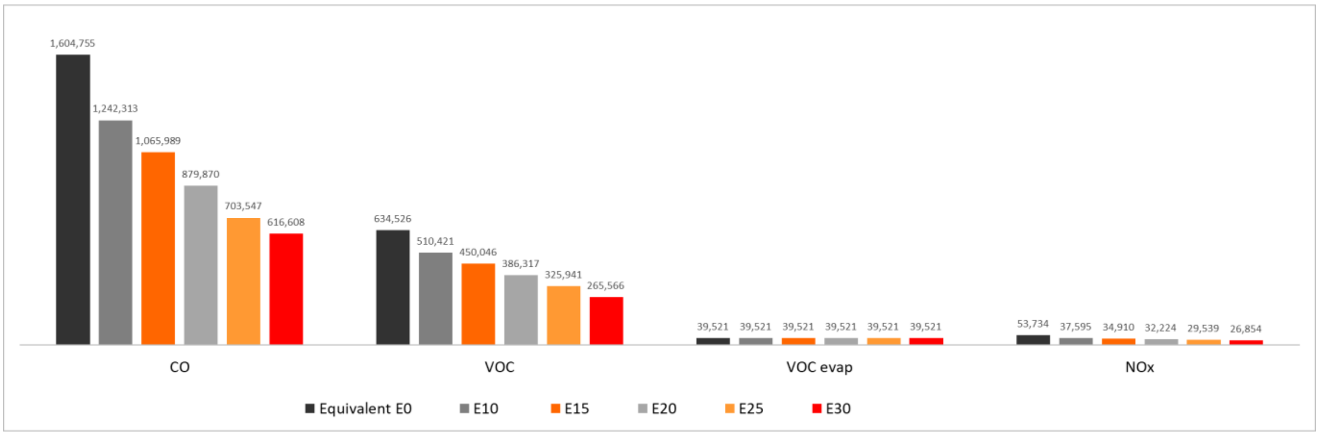
The emissions of the non-regulated parameters in kg per day are depicted below.

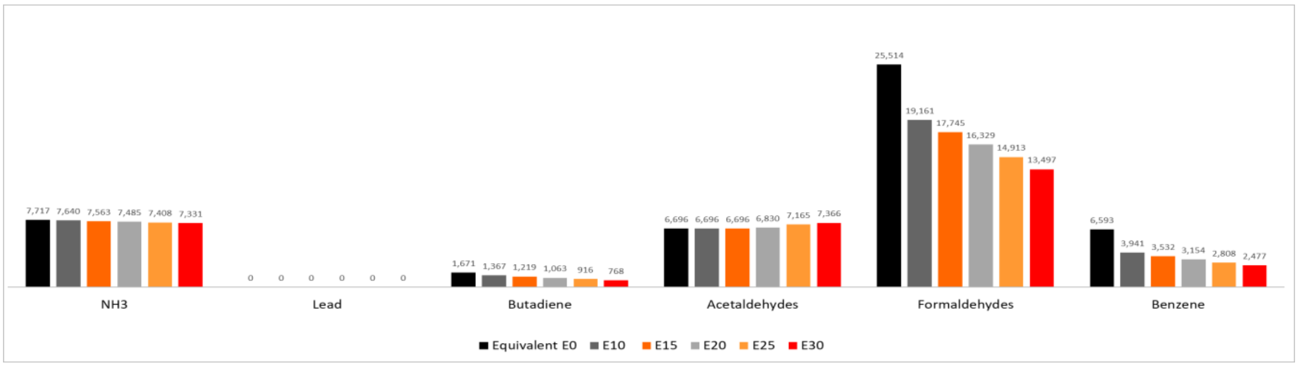
As observed, emissions that decreased with the addition of ethanol for the RON 87 regular and RON 92 premium grades are CO, VOC, NO_X, SO_X, NH_3, butadiene, formaldehydes, benzene, CO_2, N_2O, PM2.5 and PM10. Acetaldehydes emissions increased as of E20. CO_2 emissions are much higher than any other emissions.

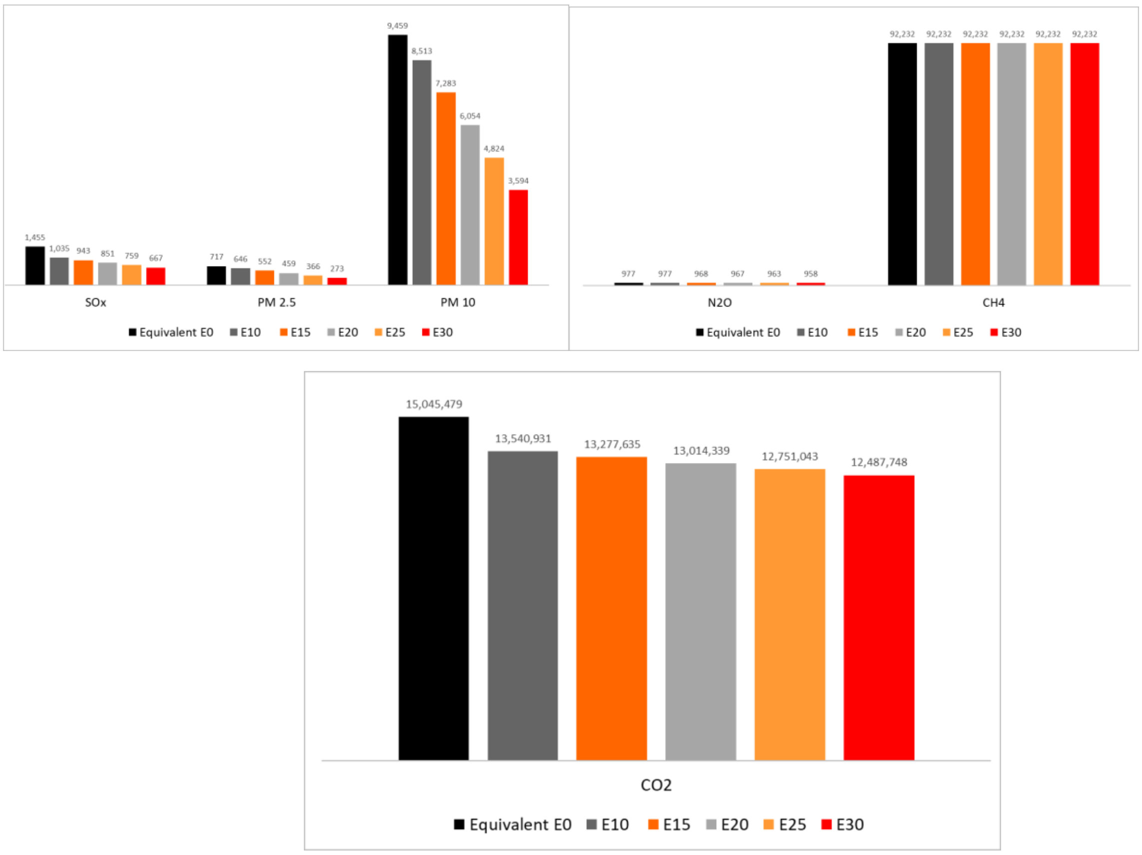
Analyzing the comparison of emissions from the RON 87 and RON 92 grades it is shown that all emissions are the same except for benzene emissions.

Figure 176: Ecuador regular RON 87 grade: Emissions of non-regulated parameters per ethanol blend

kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	1,604,755	1,242,313	1,065,989	879,870	703,547	616,608
VOC	634,526	510,421	450,046	386,317	325,941	265,566
VOC evap	39,521	39,521	39,521	39,521	39,521	39,521
NOx	53,734	37,595	34,910	32,224	29,539	26,854
SOx	1,455	1,035	943	851	759	667
NH3	7,717	7,640	7,563	7,485	7,408	7,331
Lead	0	0	0	0	0	0
Butadiene	1,671	1,367	1,219	1,063	916	768
Acetaldehydes	6,696	6,696	6,696	6,830	7,165	7,366
Formaldehydes	25,514	19,161	17,745	16,329	14,913	13,497
Benzene	6,593	3,941	3,532	3,154	2,808	2,477
CO2	15,045,479	13,540,931	13,277,635	13,014,339	12,751,043	12,487,748
N2O	977	977	968	967	963	958
CH4	92,232	92,232	92,232	92,232	92,232	92,232
PM 2.5	717	646	552	459	366	273
PM 10	9,459	8,513	7,283	6,054	4,824	3,594







Source: HCX

Figure 177: Ecuador premium RON 92 grade: Emissions of non-regulated parameters per ethanol blend

kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	1,604,755	1,242,313	1,065,989	879,870	703,547	616,608
VOC	634,526	510,421	450,046	386,317	325,941	265,566
VOC evap	39,521	39,521	39,521	39,521	39,521	39,521
NOx	53,734	37,595	34,910	32,224	29,539	26,854
SOx	1,455	1,035	943	851	759	667
NH3	7,717	7,640	7,563	7,485	7,408	7,331
Lead	0	0	0	0	0	0
Butadiene	1,671	1,367	1,219	1,063	916	768
Acetaldehydes	6,696	6,696	6,696	6,830	7,165	7,366
Formaldehydes	25,514	19,161	17,745	16,329	14,913	13,497
Benzene	6,593	3,941	3,532	3,154	2,808	2,477
CO2	15,045,479	13,540,931	13,277,635	13,014,339	12,751,043	12,487,748
N2O	977	977	968	967	963	958
CH4	92,232	92,232	92,232	92,232	92,232	92,232
PM 2.5	717	646	552	459	366	273
PM 10	9,459	8,513	7,283	6,054	4,824	3,594

Source: HCX

Graphs will not be included here as they are very similar to the graphs obtained from regular gasoline grade.

El Salvador

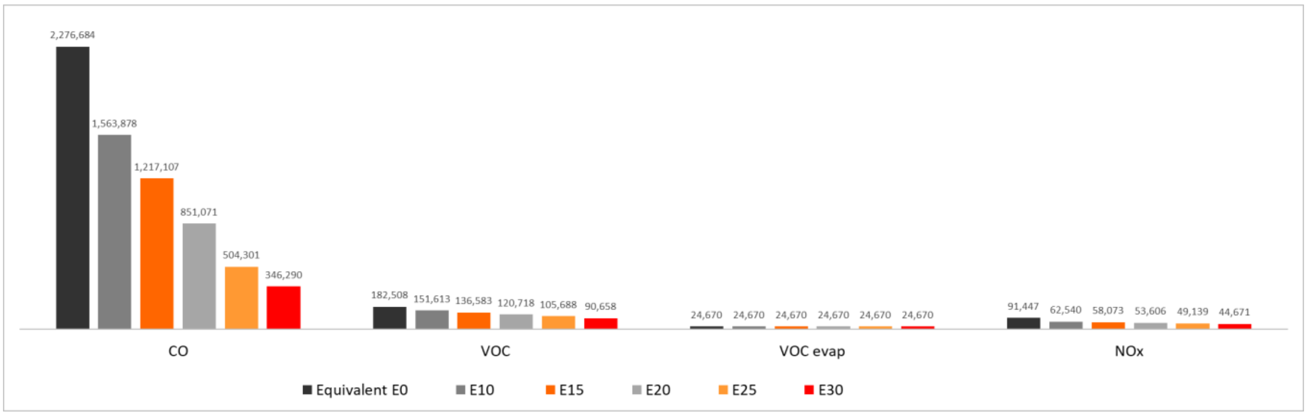
The emissions of the non-regulated parameters in kg per day are depicted below.

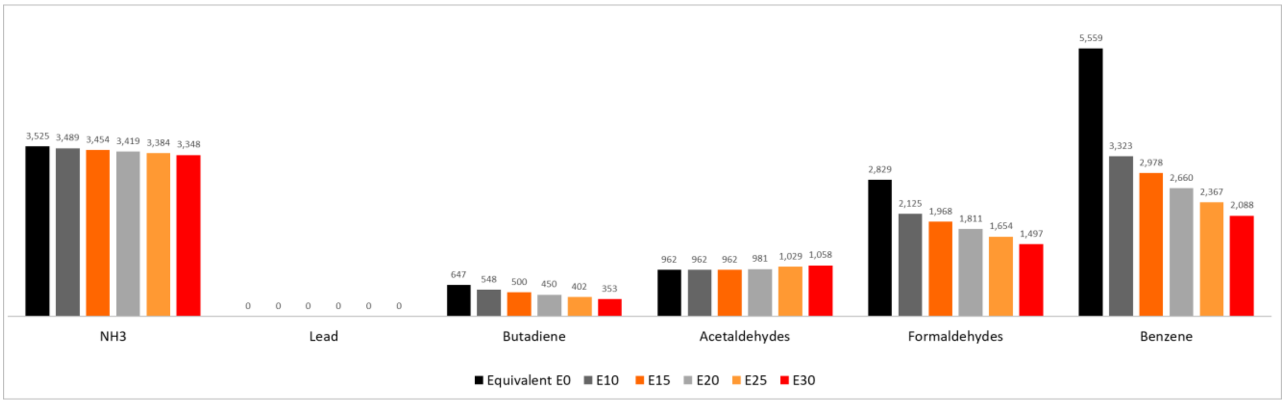
As observed, emissions that decreased with the addition of ethanol for the RON 88 regular and RON 95 premium grades are CO, VOC, NO_X, SO_X, NH_3, butadiene, formaldehydes, benzene, CO_2, N_2O, PM2.5 and PM10. Acetaldehydes emissions increased as of E20.

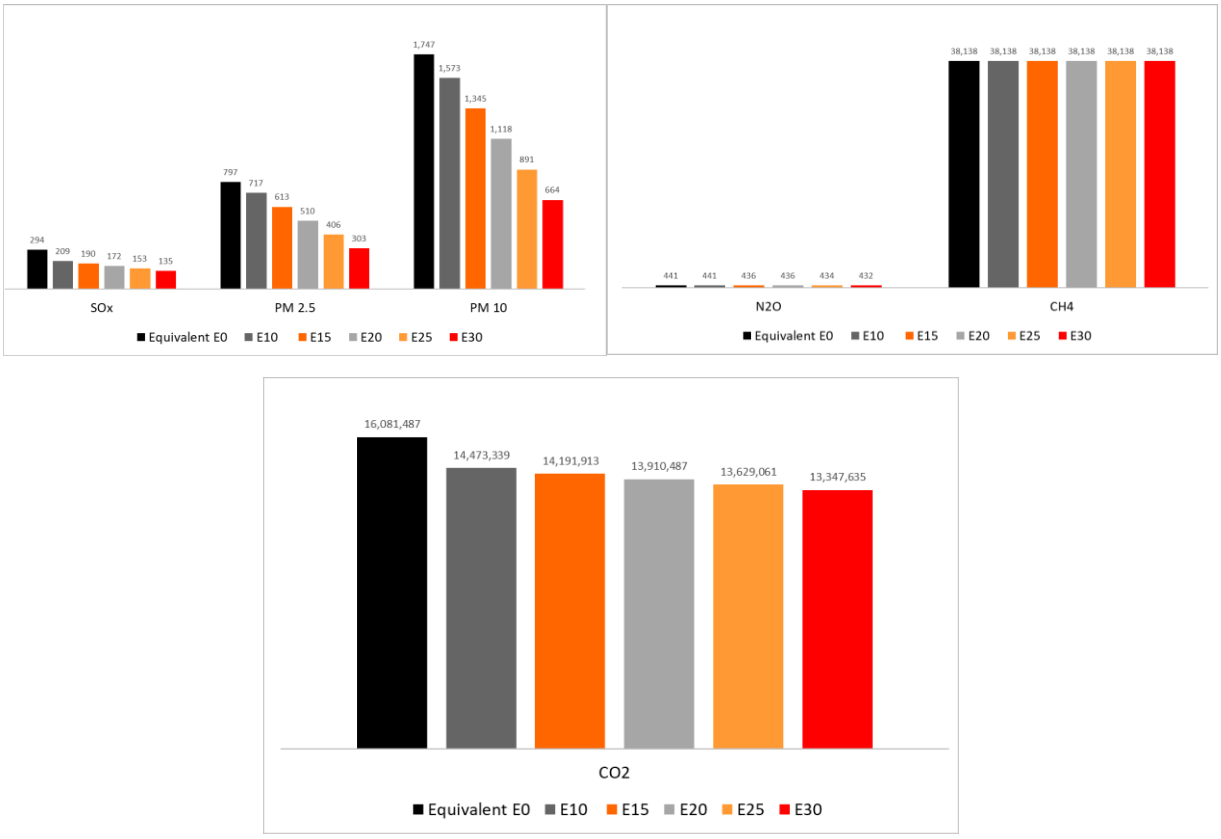
CO and CO_2 emissions are quite high in comparison to other emissions.

Figure 178: El Salvador regular RON 88: Emissions of non-regulated parameters per ethanol blend

kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	2,276,684	1,563,878	1,217,107	851,071	504,301	346,290
VOC	182,508	151,613	136,583	120,718	105,688	90,658
VOC evap	24,670	24,670	24,670	24,670	24,670	24,670
NOx	91,447	62,540	58,073	53,606	49,139	44,671
SOx	294	209	190	172	153	135
NH3	3,525	3,489	3,454	3,419	3,384	3,348
Lead	0	0	0	0	0	0
Butadiene	647	548	500	450	402	353
Acetaldehydes	962	962	962	981	1,029	1,058
Formaldehydes	2,829	2,125	1,968	1,811	1,654	1,497
Benzene	5,559	3,323	2,978	2,660	2,367	2,088
CO2	16,081,487	14,473,339	14,191,913	13,910,487	13,629,061	13,347,635
N2O	441	441	436	436	434	432
CH4	38,138	38,138	38,138	38,138	38,138	38,138
PM 2.5	797	717	613	510	406	303
PM 10	1,747	1,573	1,345	1,118	891	664







Source: HCX

Figure 179: El Salvador premium RON 95: Emissions of non-regulated parameters per ethanol blend

kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	2,275,096	1,562,348	1,215,606	849,601	502,858	344,876
VOC	182,108	151,242	136,226	120,376	105,360	90,344
VOC evap	24,670	24,670	24,670	24,670	24,670	24,670
NOx	91,355	62,479	58,016	53,553	49,091	44,628
SOx	250	178	162	146	130	114
NH3	3,512	3,477	3,442	3,407	3,372	3,337
Lead	0	0	0	0	0	0
Butadiene	644	546	498	447	399	351
Acetaldehydes	958	958	958	978	1,026	1,054
Formaldehydes	2,823	2,120	1,964	1,807	1,650	1,493
Benzene	4,572	2,733	2,449	2,187	1,947	1,717
CO2	16,081,487	14,473,339	14,191,913	13,910,487	13,629,061	13,347,635
N2O	426	426	422	422	420	418
CH4	38,138	38,138	38,138	38,138	38,138	38,138
PM 2.5	797	717	613	510	406	303
PM 10	1,747	1,573	1,345	1,118	891	664

Graphs will not be included here as they are very similar to the graphs obtained from regular gasoline grade.

Emissions of NO_X, NH_3, butadiene, acetaldehydes, formaldehydes, benzene and N_2O of gasoline RON 88 decreased and emissions of CO increased compared to gasoline RON 95. The difference, however, is not significant.

Guatemala

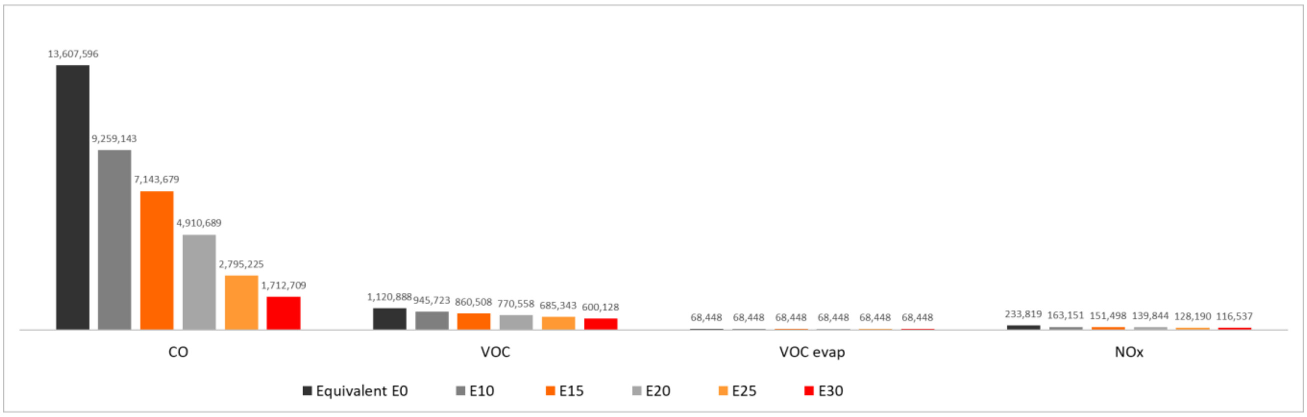
The emissions of the non-regulated parameters in kg per day are depicted below.

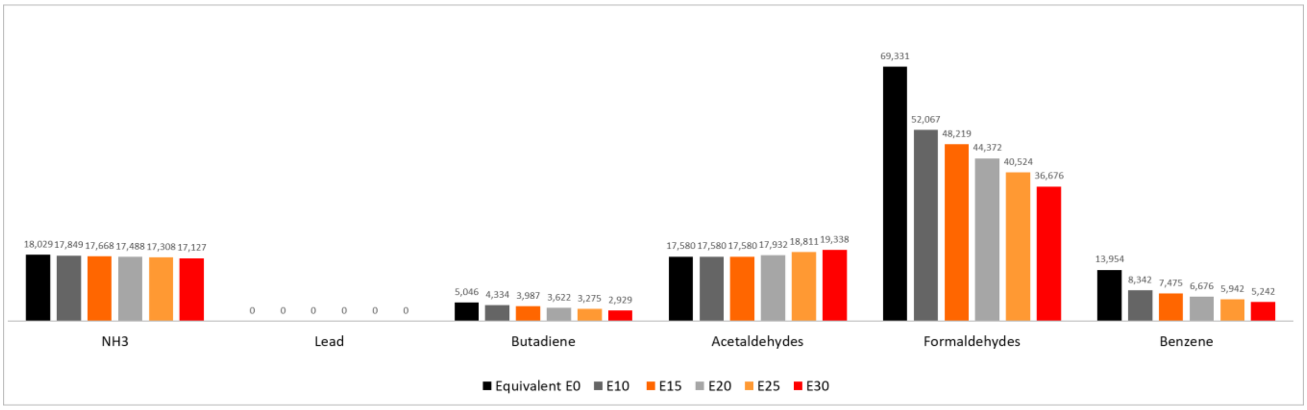
As observed, emissions that decreased with the addition of ethanol for the RON 91 regular and RON 95 premium grades are CO, VOC, NO_X, SO_X, NH_3, butadiene, formaldehydes, benzene, CO_2, N_2O, PM2.5 and PM10. Acetaldehydes emissions increased as of E20.

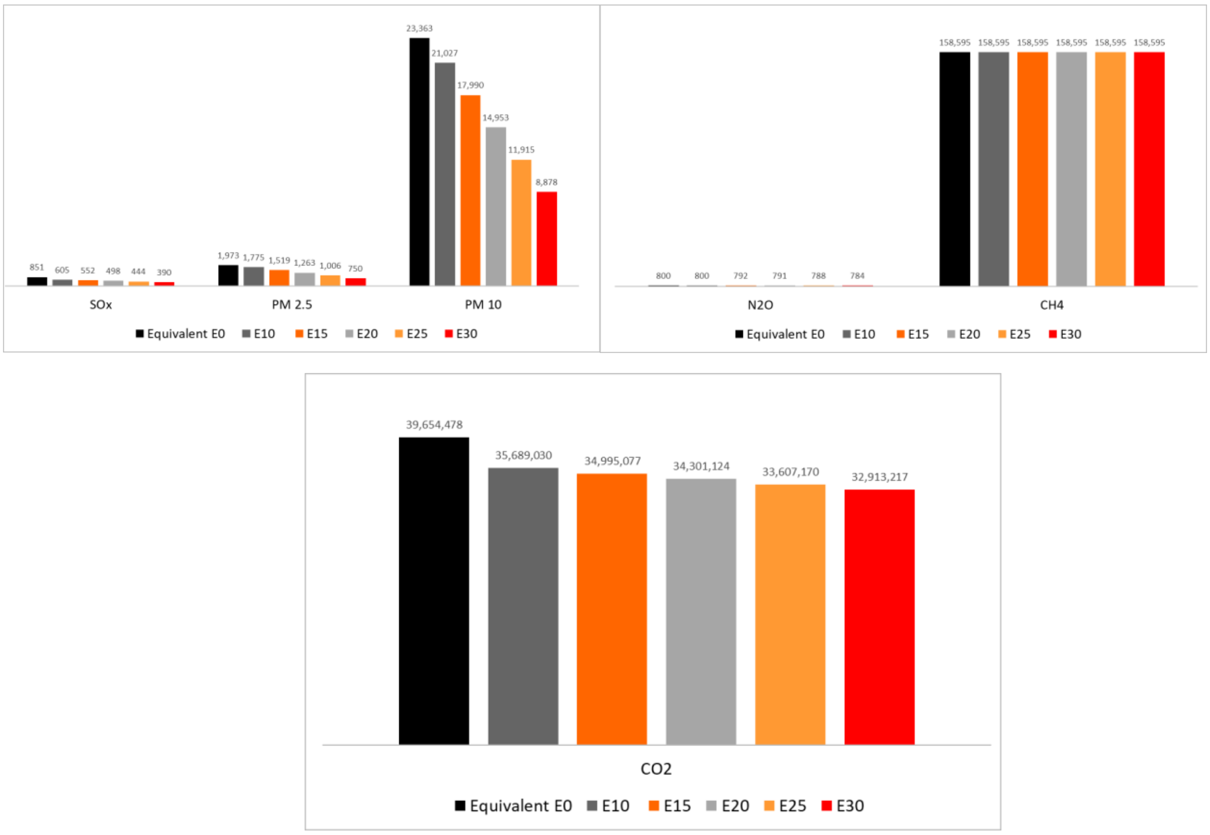
Analyzing the comparison of emissions from the regular and premium grades it is shown emissions are different, which means that the BOB used for both grades is different.

Figure 180: Guatemala regular RON 91: Emissions of non-regulated parameters per ethanol blend

kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	13,607,596	9,259,143	7,143,679	4,910,689	2,795,225	1,712,709
VOC	1,120,888	945,723	860,508	770,558	685,343	600,128
VOC evap	68,448	68,448	68,448	68,448	68,448	68,448
NOx	233,819	163,151	151,498	139,844	128,190	116,537
SOx	851	605	552	498	444	390
NH3	18,029	17,849	17,668	17,488	17,308	17,127
Lead	0	0	0	0	0	0
Butadiene	5,046	4,334	3,987	3,622	3,275	2,929
Acetaldehydes	17,580	17,580	17,580	17,932	18,811	19,338
Formaldehydes	69,331	52,067	48,219	44,372	40,524	36,676
Benzene	13,954	8,342	7,475	6,676	5,942	5,242
CO2	39,654,478	35,689,030	34,995,077	34,301,124	33,607,170	32,913,217
N2O	800	800	792	791	788	784
CH4	158,595	158,595	158,595	158,595	158,595	158,595
PM 2.5	1,973	1,775	1,519	1,263	1,006	750
PM 10	23,363	21,027	17,990	14,953	11,915	8,878







Source: HCX

Figure 181: Guatemala premium RON 95: Emissions of non-regulated parameters per ethanol blend

kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	13,606,477	9,258,053	7,142,603	4,909,628	2,794,178	1,711,675
VOC	1,120,790	945,625	860,410	770,461	685,245	600,030
VOC evap	68,448	68,448	68,448	68,448	68,448	68,448
NOx	233,644	163,031	151,386	139,741	128,096	116,451
SOx	773	550	501	452	403	354
NH3	18,013	17,833	17,653	17,472	17,292	17,112
Lead	0	0	0	0	0	0
Butadiene	5,045	4,333	3,987	3,621	3,274	2,928
Acetaldehydes	17,579	17,579	17,579	17,931	18,810	19,337
Formaldehydes	69,329	52,066	48,218	44,371	40,523	36,675
Benzene	18,456	11,032	9,886	8,830	7,859	6,933
CO2	39,654,478	35,689,030	34,995,077	34,301,124	33,607,170	32,913,217
N2O	785	785	778	777	774	770
CH4	158,595	158,595	158,595	158,595	158,595	158,595
PM 2.5	1,973	1,775	1,519	1,263	1,006	750
PM 10	23,363	21,027	17,990	14,953	11,915	8,878

Source: HCX

Graphs will not be included here as they are very similar to the graphs obtained from regular gasoline grade.

Emissions of CO, VOC, NO_X, SO_X, NH_3, benzene, N_2O, of gasoline RON 91 regular decreased compared to gasoline RON 95 premium. Emissions of benzene increased. The difference is, however, not significant.

Honduras

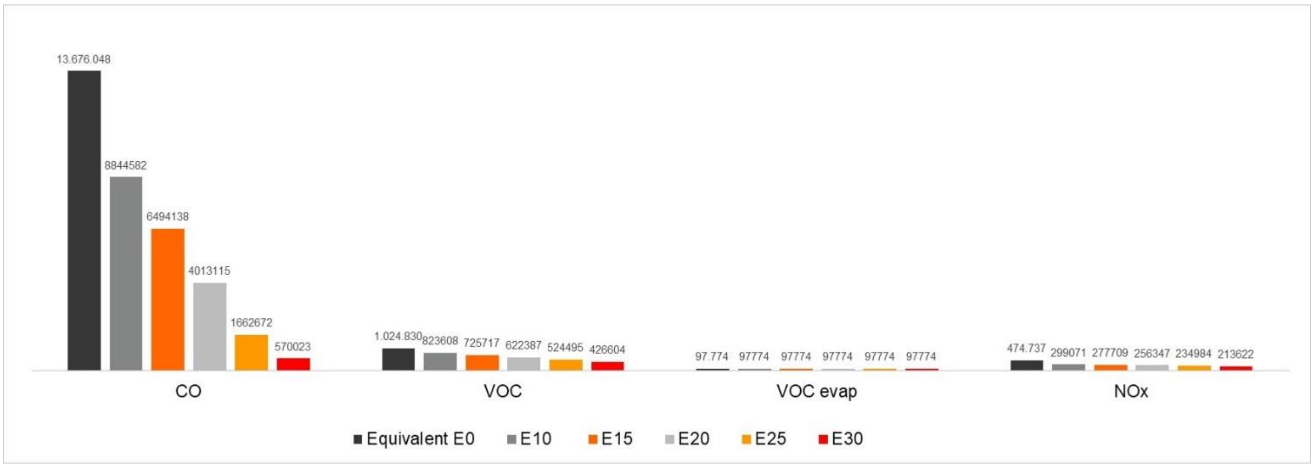
The emissions of the non-regulated parameters in kg per day are depicted below.

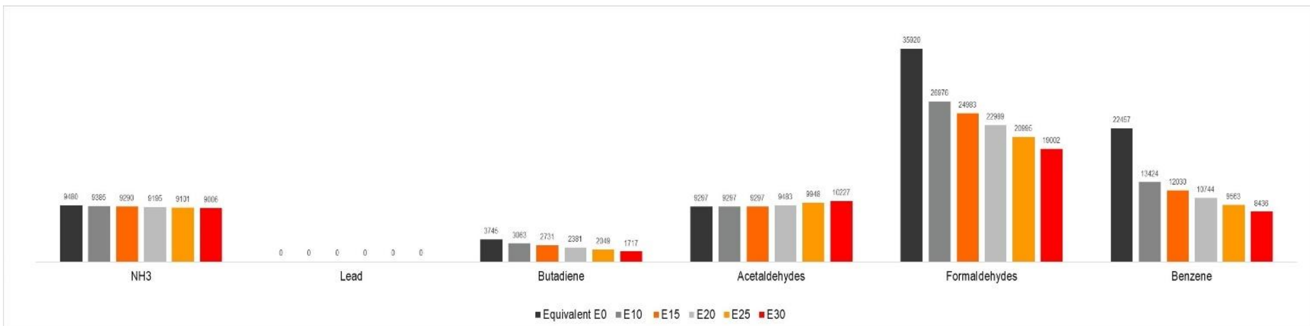
As observed, emissions that decreased with the addition of ethanol for the RON 91 regular and RON 95 premium grades are CO, VOC, NO_X, SO_X, NH_3, butadiene, formaldehydes, benzene, CO_2, N_2O, PM2.5 and PM10. Acetaldehydes emissions increased as of E20.

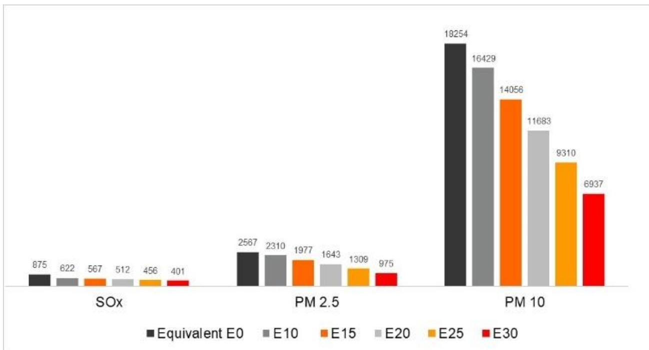
Analyzing the comparison of emissions from the regular and premium grades it is shown emissions are different, which means that the BOB used for both grades is different.

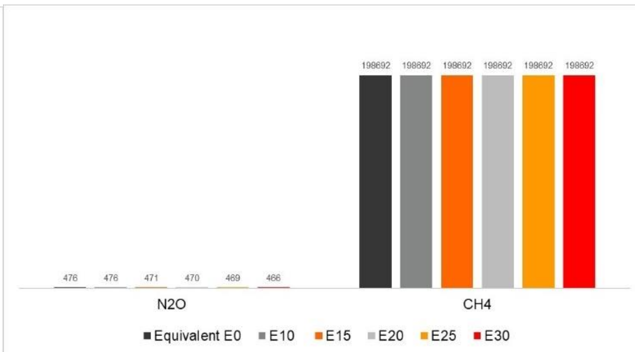
Figure 182: Honduras regular RON 91: Emissions of non-regulated parameters per ethanol blend

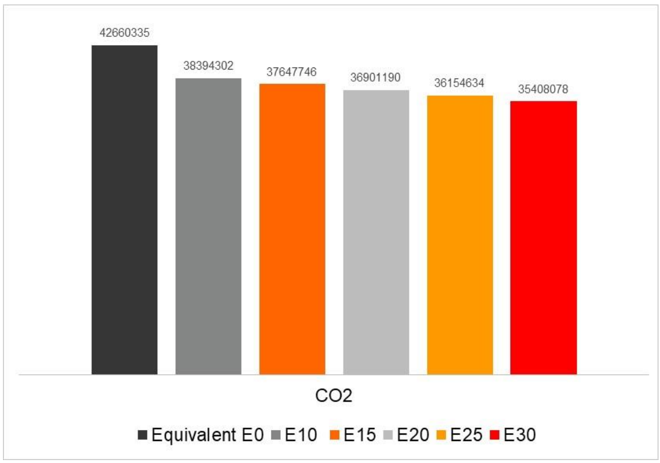
kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	13676048	8844582	6494138	4013115	1662672	570023
VOC	1024830	823608	725717	622387	524495	426604
VOC evap	97774	97774	97774	97774	97774	97774
NOx	474737	299071	277709	256347	234984	213622
SOx	875	622	567	512	456	401
NH3	9480	9385	9290	9195	9101	9006
Lead	0	0	0	0	0	0
Butadiene	3745	3063	2731	2381	2049	1717
Acetaldehydes	9297	9297	9297	9483	9948	10227
Formaldehydes	35920	26976	24983	22989	20995	19002
Benzene	22457	13424	12030	10744	9563	8436
CO2	42660335	38394302	37647746	36901190	36154634	35408078
N2O	476	476	471	470	469	466
CH4	198692	198692	198692	198692	198692	198692
PM 2.5	2567	2310	1977	1643	1309	975
PM 10	18254	16429	14056	11683	9310	6937











Source: HCX

Figure 183: Honduras premium RON 95: Emissions of non-regulated parameters per ethanol blend

kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	13675677	8844224	6493787	4012771	1662334	569693
VOC	1024797	823575	725684	622354	524462	426571
VOC evap	97774	97774	97774	97774	97774	97774
NOx	474709	299051	277690	256330	234969	213608
SOx	787	560	510	460	410	361
NH3	9476	9381	9287	9192	9097	9002
Lead	0	0	0	0	0	0
Butadiene	3745	3063	2731	2381	2049	1717
Acetaldehydes	9297	9297	9297	9483	9948	10227
Formaldehydes	35920	26976	24982	22989	20995	19002
Benzene	18535	11080	9929	8868	7893	6963
CO2	42660335	38394302	37647746	36901190	36154634	35408078
N2O	472	472	467	467	465	463
CH4	198692	198692	198692	198692	198692	198692
PM 2.5	2567	2310	1977	1643	1309	975
PM 10	18254	16429	14056	11683	9310	6937

Source: HCX

Graphs will not be included here as they are very similar to the graphs obtained from regular gasoline grade.

Emissions of CO, VOC, NO_x, SO_x, NH_3, benzene, of gasoline RON 91 decreased compared to gasoline RON 95 premium and emissions of N_2O increased. The difference, however, is not significant.

Jamaica

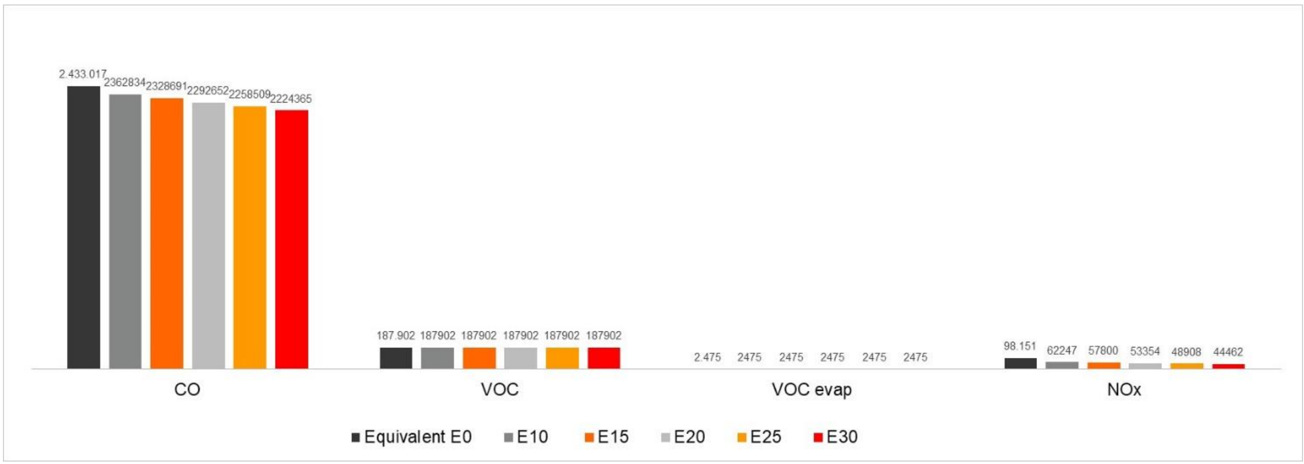
The emissions of the non-regulated parameters in kg per day are depicted below.

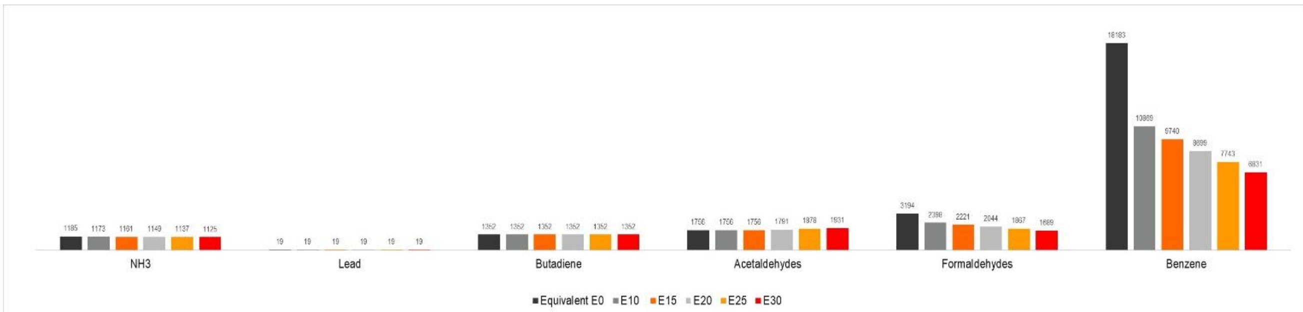
As observed, emissions that decreased with the addition of ethanol for the regular AKI 87 EX and premium AKI 90 EX gasoline grades are CO, NO_X, SO_X, NH_3, formaldehydes, benzene, CO2, N_2O, PM 2.5 and PM 10. Emissions of acetaldehydes increase as of E20.

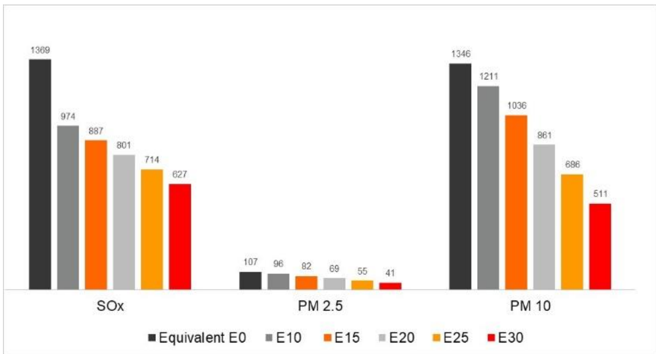
Analyzing the comparison of emissions from the regular and gasoline grades it is shown that all emissions are the same, which indicates that they use the same BOB.

Figure 184: Jamaica regular and premium grades AKI 87 EX and AKI 90 EX: Emissions of non-regulated parameters per ethanol blend

kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	2433017	2362834	2328691	2292652	2258509	2224365
VOC	187902	187902	187902	187902	187902	187902
VOC evap	2475	2475	2475	2475	2475	2475
NOx	98151	62247	57800	53354	48908	44462
SOx	1369	974	887	801	714	627
NH3	1185	1173	1161	1149	1137	1125
Lead	19	19	19	19	19	19
Butadiene	1352	1352	1352	1352	1352	1352
Acetaldehydes	1756	1756	1756	1791	1878	1931
Formaldehydes	3194	2398	2221	2044	1867	1689
Benzene	18183	10869	9740	8699	7743	6831
CO2	3039805	2735825	2682628	2629431	2576235	2523038
N2O	729	729	722	721	719	715
CH4	20714	20714	20714	20714	20714	20714
PM 2.5	107	96	82	69	55	41
PM 10	1346	1211	1036	861	686	511



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714
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82
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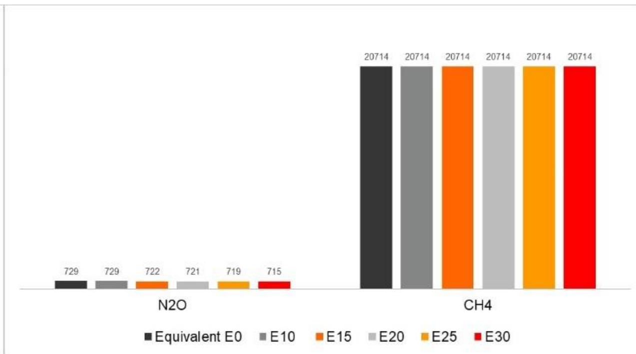
SOx
PM 2.5
PM 10
Equivalent E0 E10 E15 E20 E25 E30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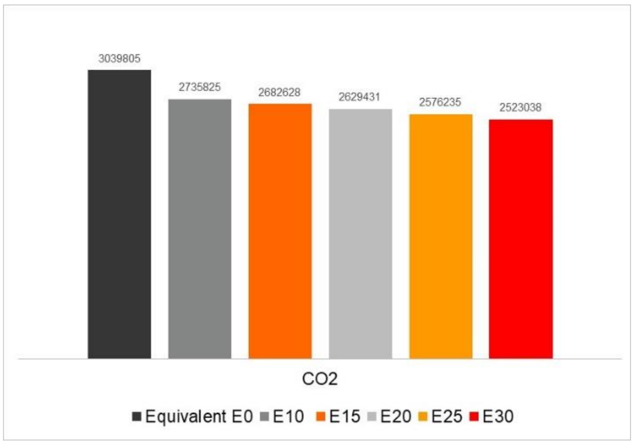
N2O
CH4
Equivalent E0 E10 E15 E20 E25 E30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2629431
2576235
2523038
CO2
Equivalent E0 E10 E15 E20 E25 E30

Source: HCX

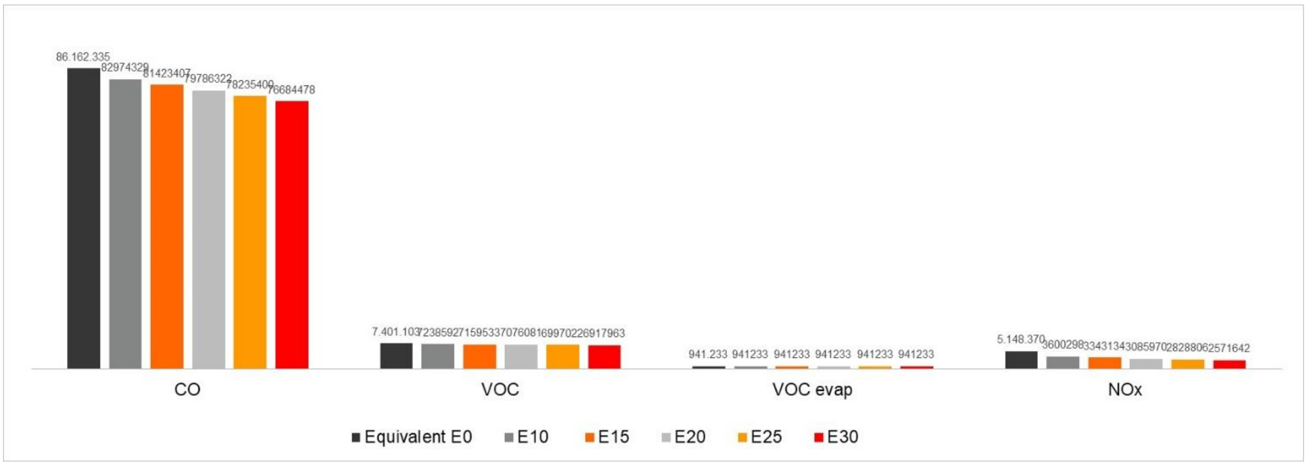
Mexico

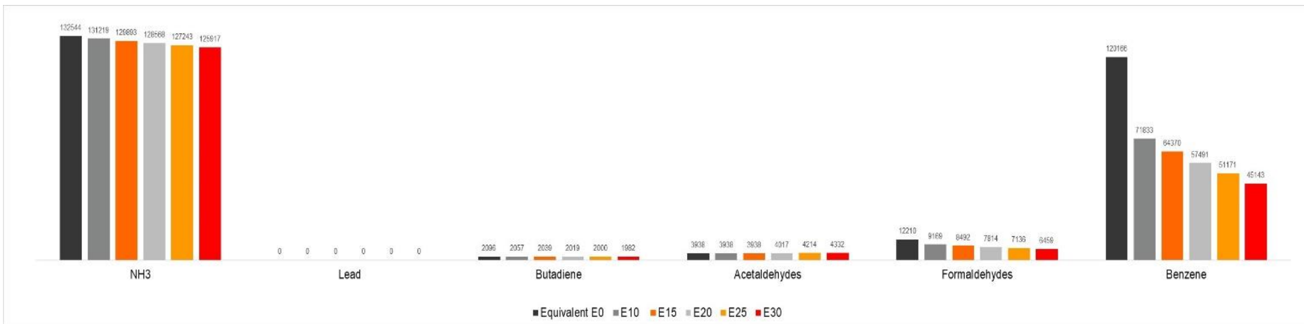
The emissions of the non-regulated parameters in kg per day are depicted below.

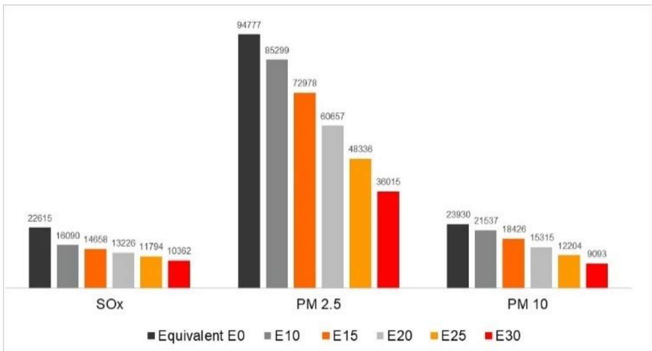
As observed, emissions that decreased with the addition of ethanol for the regular and premium gasoline grades are CO, VOC, NO_X, SO_X, NH_3, butadiene, formaldehydes, benzene, CO_2, N_2O, PM 2.5 and PM 10. Emissions of acetaldehydes increase as of E20.

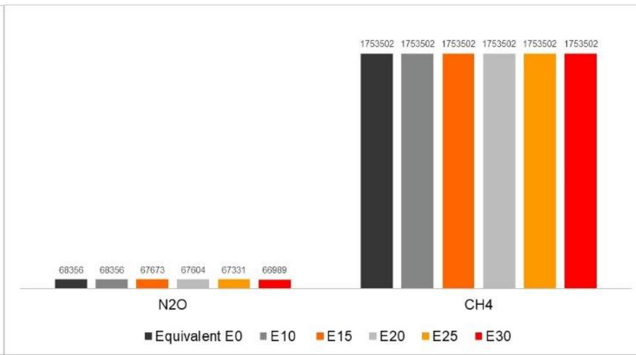
Figure 185: Mexico regular grade: Emissions of non-regulated parameters per gasoline blend

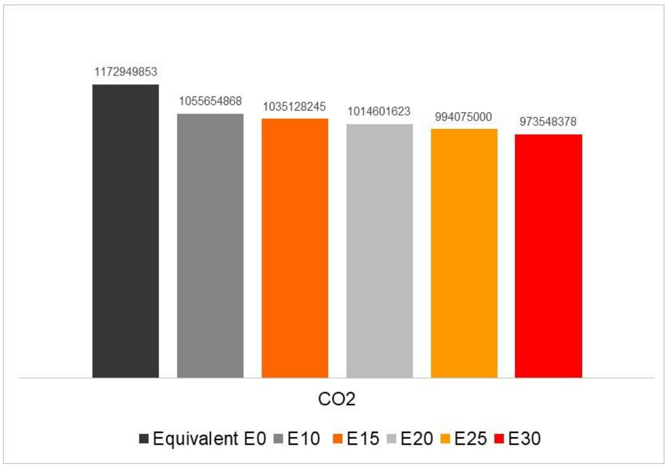
kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	86162335	82974329	81423407	79786322	78235400	76684478
VOC	7401103	7238592	7159533	7076081	6997022	6917963
VOC evap	941233	941233	941233	941233	941233	941233
NOx	5148370	3600298	3343134	3085970	2828806	2571642
SOx	22615	16090	14658	13226	11794	10362
NH3	132544	131219	129893	128568	127243	125917
Lead	0	0	0	0	0	0
Butadiene	2096	2057	2039	2019	2000	1982
Acetaldehydes	3938	3938	3938	4017	4214	4332
Formaldehydes	12210	9169	8492	7814	7136	6459
Benzene	120166	71833	64370	57491	51171	45143
CO2	1172949853	1055654868	1035128245	1014601623	994075000	973548378
N2O	68356	68356	67673	67604	67331	66989
CH4	1753502	1753502	1753502	1753502	1753502	1753502
PM 2.5	94777	85299	72978	60657	48336	36015
PM 10	23930	21537	18426	15315	12204	9093











Source: HCX

Figure 186: Mexico premium grade: Emissions of non-regulated parameters per gasoline blend

kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	86033093	82849869	81301273	79666644	78118048	76569453
VOC	7379497	7217454	7138622	7055411	6976579	6897748
VOC evap	941233	941233	941233	941233	941233	941233
NOx	5130455	3587770	3331501	3075232	2818963	2562693
SOx	17358	12351	11251	10152	9053	7954
NH3	131765	130448	129130	127812	126495	125177
Lead	0	0	0	0	0	0
Butadiene	2086	2048	2029	2010	1991	1973
Acetaldehydes	3923	3923	3923	4001	4198	4315
Formaldehydes	12168	9138	8463	7787	7112	6437
Benzene	101883	60904	54577	48744	43386	38275
CO2	1172949853	1055654868	1035128245	1014601623	994075000	973548378
N2O	64820	64820	64172	64107	63848	63524
CH4	1753502	1753502	1753502	1753502	1753502	1753502
PM 2.5	94777	85299	72978	60657	48336	36015
PM 10	23930	21537	18426	15315	12204	9093

Source: HCX

Graphs will not be included here as they are very similar to the graphs obtained from regular gasoline grade.

As observed, emissions that decreased with the addition of ethanol for the regular and premium ethanol blend grades are CO, VOC, NO_X, SO_X, NH_3, butadiene, formaldehydes, benzene, CO_2, N_2O, PM 2.5 and PM 10. Emissions of acetaldehydes increase as of E20.

Figure 187: Mexico regular E5.8 grade: Emissions of non-regulated parameters per gasoline blend

kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	86200787	83011358	81459744	79821929	78270315	76718701
VOC	7407531	7244881	7165754	7082231	7003104	6923977
VOC evap	941233	941233	941233	941233	941233	941233
NOx	5153700	3604025	3346595	3089165	2831734	2574304
SOx	24179	17203	15672	14141	12610	11079
NH3	132776	131448	130121	128793	127465	126137
Lead	0	0	0	0	0	0
Butadiene	2098	2060	2041	2022	2003	1984
Acetaldehydes	3943	3943	3943	4022	4219	4337
Formaldehydes	12222	9179	8500	7822	7144	6465
Benzene	434007	259441	232488	207643	184817	163046
CO2	1172949853	1055654868	1035128245	1014601623	994075000	973548378
N2O	69408	69408	68714	68645	68367	68020
CH4	1753502	1753502	1753502	1753502	1753502	1753502
PM 2.5	94777	85299	72978	60657	48336	36015
PM 10	23930	21537	18426	15315	12204	9093

Source: HCX

Graphs will not be included here as they are very similar to the graphs obtained from the regular gasoline grade.

Figure 188: Mexico premium E5.8 grade: Emissions of non-regulated parameters per gasoline blend

kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	86220014	83029873	81477913	79839733	78287772	76735812
VOC	7410745	7248026	7168865	7085306	7006145	6926984
VOC evap	941233	941233	941233	941233	941233	941233
NOx	5156365	3605889	3348326	3090762	2833199	2575635
SOx	24961	17759	16179	14598	13018	11437
NH3	132892	131563	130234	128905	127576	126247
Lead	0	0	0	0	0	0
Butadiene	2100	2061	2043	2023	2004	1986
Acetaldehydes	3945	3945	3945	4024	4221	4340
Formaldehydes	12228	9183	8505	7826	7147	6469
Benzene	141495	84583	75795	67695	60254	53156
CO2	1172949853	1055654868	1035128245	1014601623	994075000	973548378
N2O	69934	69934	69235	69165	68885	68536
CH4	1753502	1753502	1753502	1753502	1753502	1753502
PM 2.5	94777	85299	72978	60657	48336	36015
PM 10	23930	21537	18426	15315	12204	9093

Source: HCX

Graphs will not be included here as they are very similar to the graphs obtained from premium gasoline grade.

Different BOB is used for ethanol blend grades compared to gasoline grades.

Nicaragua

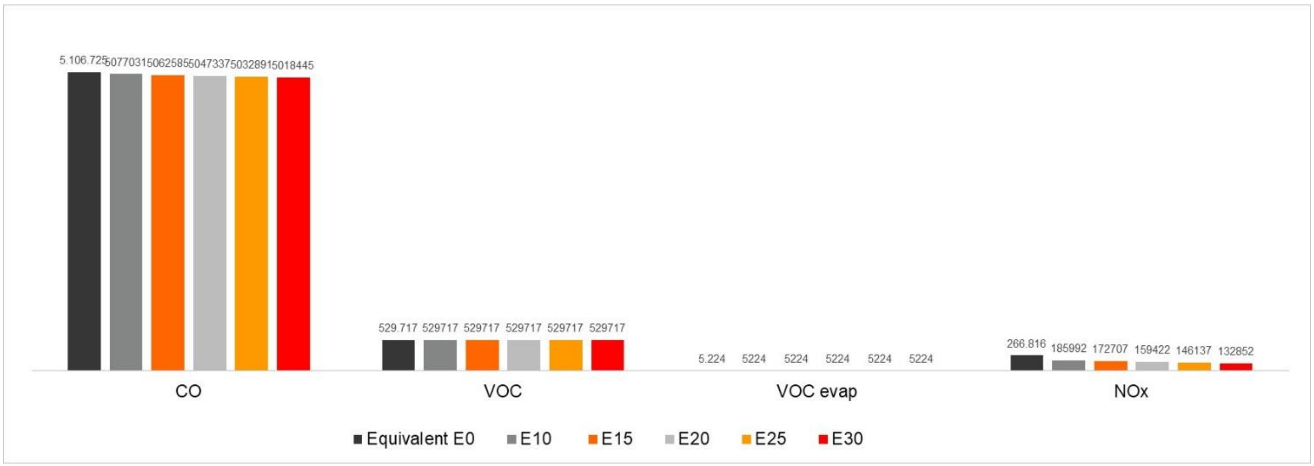
The emissions of the non-regulated parameters in kg per day are depicted below.

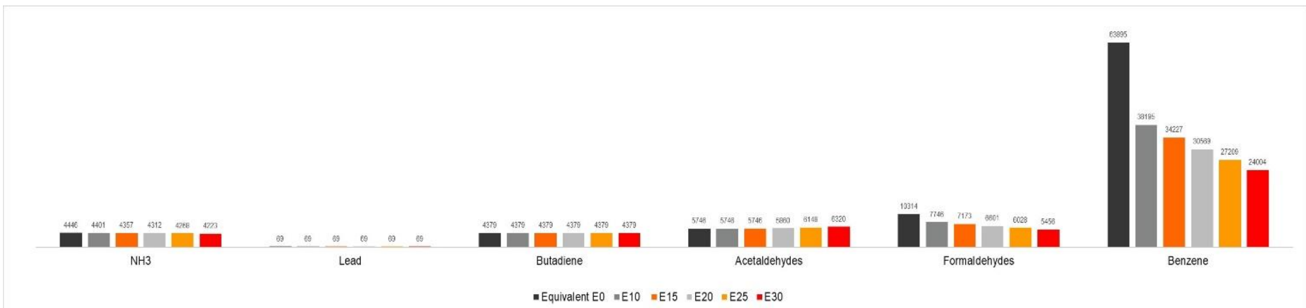
As observed, emissions that decreased with the addition of ethanol for the regular RON 88 and premium RON 95 gasoline grade are CO, formaldehydes, and benzene. Benzene emissions decrease significantly when ethanol is added. CO_2 emissions are really high compared to the other emissions.

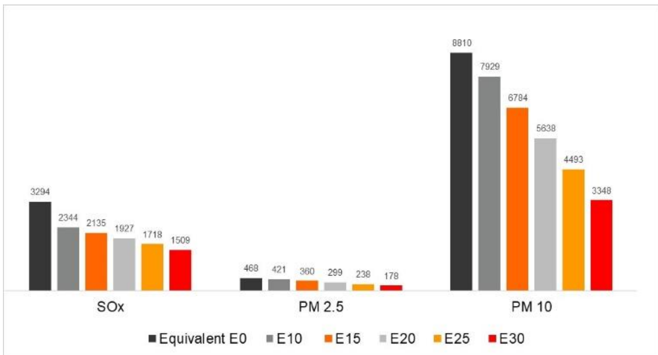
Analyzing the comparison of emissions from the regular and premium grades it is shown that all emissions are the same, which indicates that they use the same BOB.

Figure 189: Nicaragua regular and premium grades: Emissions of non-regulated parameters per ethanol blend

kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	5106725	5077031	5062585	5047337	5032891	5018445
VOC	529717	529717	529717	529717	529717	529717
VOC evap	5224	5224	5224	5224	5224	5224
NOx	266816	185992	172707	159422	146137	132852
SOx	3294	2344	2135	1927	1718	1509
NH3	4446	4401	4357	4312	4268	4223
Lead	69	69	69	69	69	69
Butadiene	4379	4379	4379	4379	4379	4379
Acetaldehydes	5746	5746	5746	5860	6148	6320
Formaldehydes	10314	7746	7173	6601	6028	5456
Benzene	63895	38195	34227	30569	27209	24004
CO2	10931439	9838295	9646995	9455695	9264395	9073094
N2O	1133	1133	1122	1121	1116	1110
CH4	72793	72793	72793	72793	72793	72793
PM 2.5	468	421	360	299	238	178
PM 10	8810	7929	6784	5638	4493	3348



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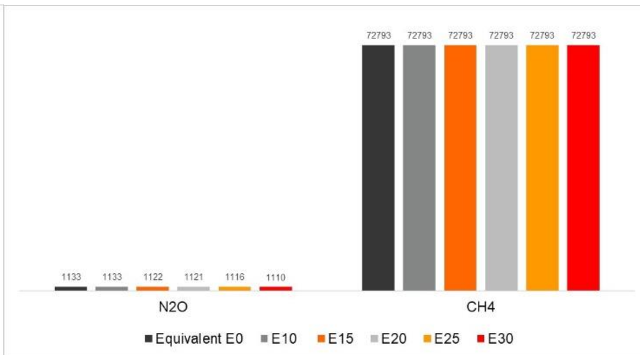
SOx
PM 2.5
PM 10
Equivalent E0
E10
E15
E20
E25
E30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1121
1116
1110
72793
72793
72793
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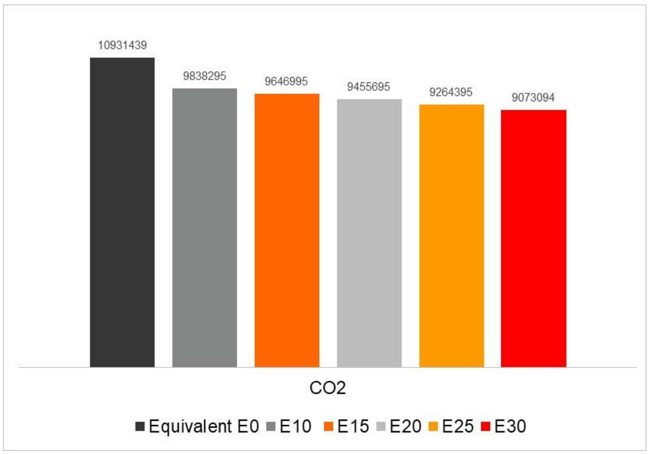
N2O
CH4
Equivalent E0
E10
E15
E20
E25
E30


10931439
9838295
9646995
9455695
9264395
9073094
CO2
Equivalent E0
E10
E15
E20
E25
E30

Source: HCX

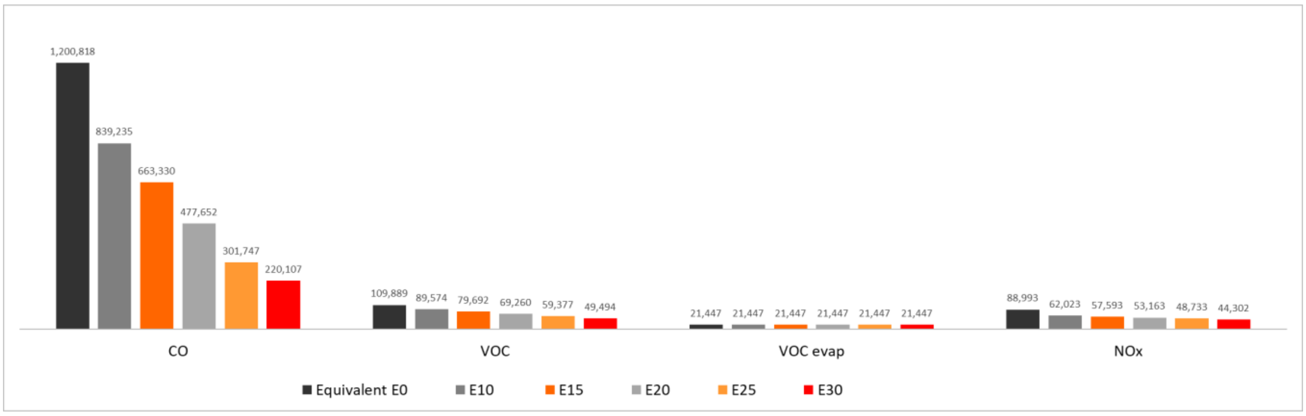
Panama

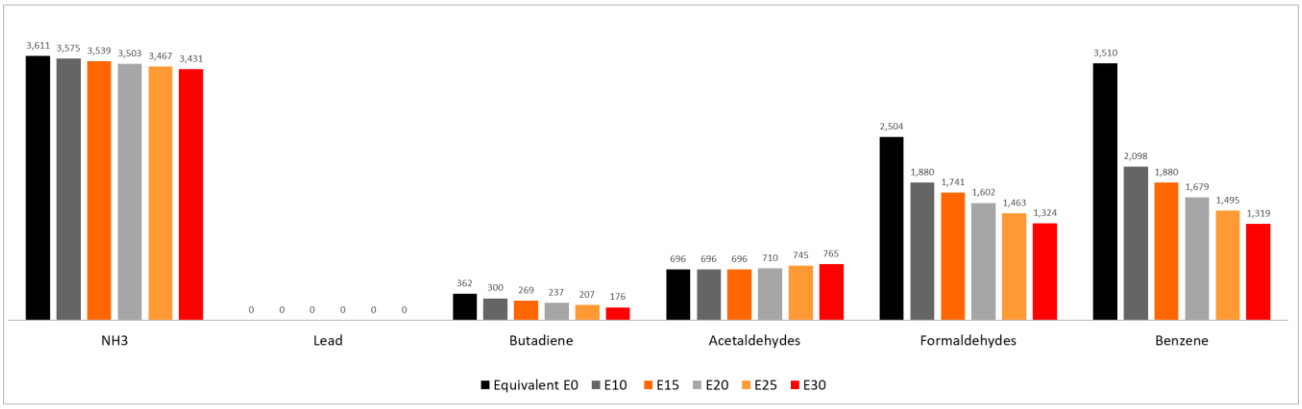
The emissions of the non-regulated parameters in kg per day are depicted below.

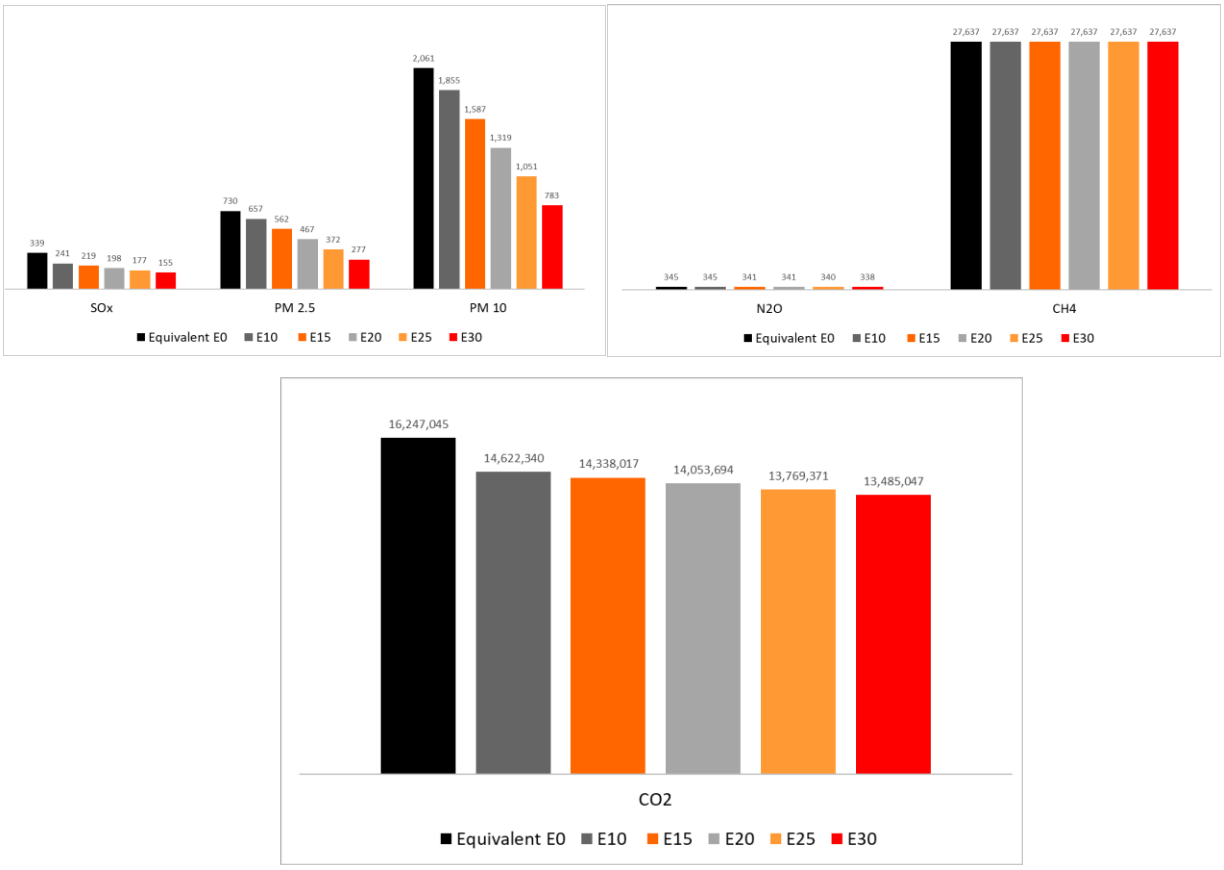
As observed, emissions that decreased with the addition of ethanol for the regular RON 91 and premium RON 95 gasoline grades are CO, VOC, NO_X, SO_X, NH_3, butadiene, formaldehydes, benzene, CO_2, N_2O, PM 2.5 and PM 10. Emissions of acetaldehydes increase as of E20.

Figure 190: Panama regular grade RON 91: Emissions of non-regulated parameters per ethanol blend

kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	1,200,818	839,235	663,330	477,652	301,747	220,107
VOC	109,889	89,574	79,692	69,260	59,377	49,494
VOC evap	21,447	21,447	21,447	21,447	21,447	21,447
NOx	88,993	62,023	57,593	53,163	48,733	44,302
SOx	339	241	219	198	177	155
NH3	3,611	3,575	3,539	3,503	3,467	3,431
Lead	0	0	0	0	0	0
Butadiene	362	300	269	237	207	176
Acetaldehydes	696	696	696	710	745	765
Formaldehydes	2,504	1,880	1,741	1,602	1,463	1,324
Benzene	3,510	2,098	1,880	1,679	1,495	1,319
CO2	16,247,045	14,622,340	14,338,017	14,053,694	13,769,371	13,485,047
N2O	345	345	341	341	340	338
CH4	27,637	27,637	27,637	27,637	27,637	27,637
PM 2.5	730	657	562	467	372	277
PM 10	2,061	1,855	1,587	1,319	1,051	783







Source: HCX

Figure 191: Panama premium grade RON 95: Emissions of non-regulated parameters per ethanol blend

kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	1,201,054	839,464	663,556	477,875	301,967	220,323
VOC	109,908	89,594	79,711	69,279	59,397	49,514
VOC evap	21,447	21,447	21,447	21,447	21,447	21,447
NOx	89,022	62,042	57,611	53,179	48,748	44,316
SOx	350	249	227	205	182	160
NH3	3,614	3,578	3,542	3,506	3,470	3,433
Lead	0	0	0	0	0	0
Butadiene	362	300	269	237	207	177
Acetaldehydes	696	696	696	710	745	766
Formaldehydes	2,504	1,880	1,742	1,603	1,464	1,325
Benzene	2,913	1,742	1,561	1,394	1,241	1,094
CO2	16,247,045	14,622,340	14,338,017	14,053,694	13,769,371	13,485,047
N2O	347	347	344	343	342	340
CH4	27,637	27,637	27,637	27,637	27,637	27,637
PM 2.5	730	657	562	467	372	277
PM 10	2,061	1,855	1,587	1,319	1,051	783

Source: HCX

Emissions of CO and benzene of gasoline RON 91 decreased compared to gasoline RON 95 and emissions of VOC, NO_x, SO_x, NH_3, N_2O increased. The difference, however, is not significant.

Graphs will not be included here as they are very similar to the graphs obtained from regular gasoline grade.

Peru

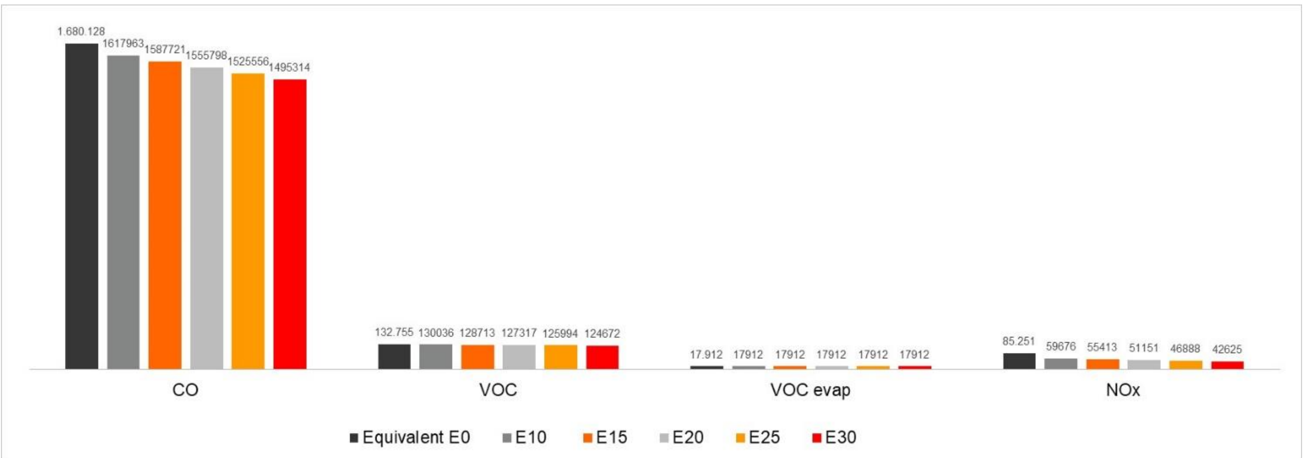
The emissions of the non-regulated parameters in kg per day are depicted below.

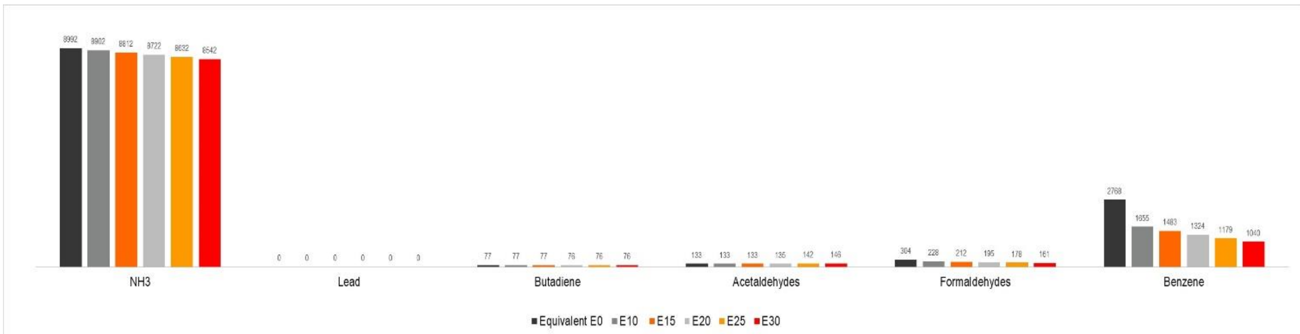
As observed, emissions that decreased with the addition of ethanol for the ethanol blend grades RON 84 EX, RON 90 EX, RON 95 EX, RON 97 EX are CO, VOC, NO_X, SO_X, formaldehydes, benzene, CO_2, N_2O, PM 2.5 and PM 10.

Analyzing the comparison of emissions from the RON 84 EX, RON 90 EX, RON 95 EX and RON 97 EX grades it is shown that emissions change, which indicates that they don´t use the same BOB.

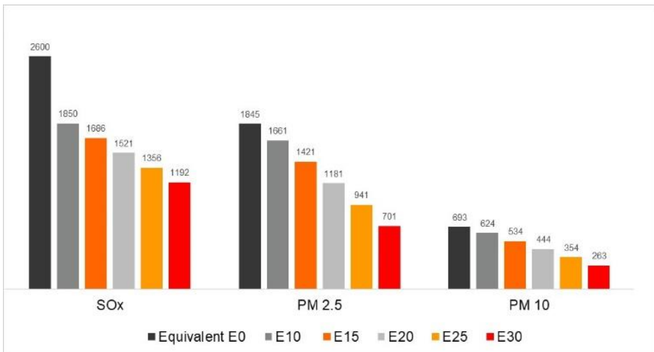
Figure 192: Peru RON 84 EX grade: Emissions of non-regulated parameters per ethanol blend

kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	1680128	1617963	1587721	1555798	1525556	1495314
VOC	132755	130036	128713	127317	125994	124672
VOC evap	17912	17912	17912	17912	17912	17912
NOx	85251	59676	55413	51151	46888	42625
SOx	2600	1850	1686	1521	1356	1192
NH3	8992	8902	8812	8722	8632	8542
Lead	0	0	0	0	0	0
Butadiene	77	77	77	76	76	76
Acetaldehydes	133	133	133	135	142	146
Formaldehydes	304	228	212	195	178	161
Benzene	2768	1655	1483	1324	1179	1040
CO2	41024533	36922080	36204150	35486221	34768292	34050362
N2O	942	942	932	931	927	923
CH4	29777	29777	29777	29777	29777	29777
PM 2.5	1845	1661	1421	1181	941	701
PM 10	693	624	534	444	354	263

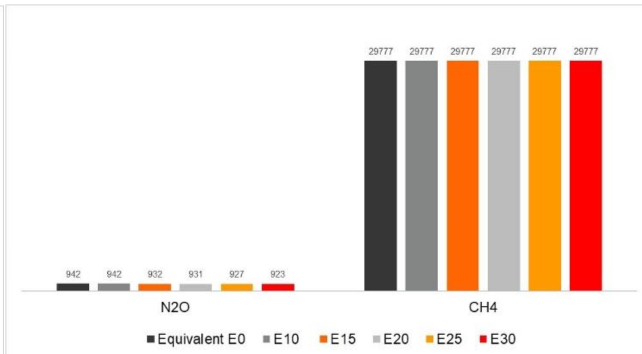




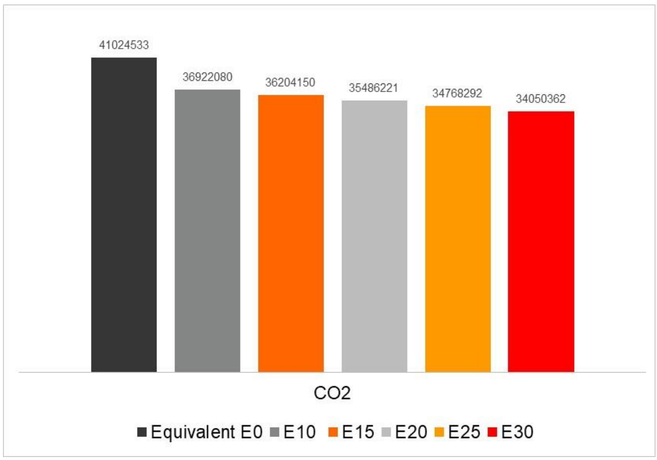
8992 8902 8812 8722 8632 8542
0 0 0 0 0 0
77 77 77 76 76 76
133 133 133 135 142 146
304 228 212 195 178 161
2768 1655 1483 1324 1179 1040
NH3
Lead
Butadiene
Acetaldehydes
Formaldehydes
Benzene
Equivalent E0 E10 E15 E20 E25 E30



2600 1850 1686 1521 1356 1192
1845 1661 1421 1181 941 701
693 624 534 444 354 263
SOx
PM 2.5
PM 10
Equivalent E0 E10 E15 E20 E25 E30



942 942 932 931 927 923
29777 29777 29777 29777 29777 29777
N2O
CH4
Equivalent E0 E10 E15 E20 E25 E30



41024533 36922080 36204150 35486221 34768292 34050362
CO2
Equivalent E0 E10 E15 E20 E25 E30

Source: HCX

Figure 193: Peru RON 90 EX grade: Emissions of non-regulated parameters per ethanol blend

kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	1680983	1618787	1588529	1556590	1526333	1496075
VOC	132863	130142	128818	127421	126097	124773
VOC evap	17912	17912	17912	17912	17912	17912
NOx	85321	59725	55459	51193	46927	42660
SOx	2639	1878	1711	1544	1377	1209
NH3	9004	8914	8824	8734	8644	8554
Lead	0	0	0	0	0	0
Butadiene	77	77	77	77	76	76
Acetaldehydes	133	133	133	136	142	146
Formaldehydes	305	229	212	195	178	161
Benzene	2768	1655	1483	1324	1179	1040
CO2	41024533	36922080	36204150	35486221	34768292	34050362
N2O	948	948	939	938	934	929
CH4	29777	29777	29777	29777	29777	29777
PM 2.5	1845	1661	1421	1181	941	701
PM 10	693	624	534	444	354	263

Source: HCX

Figure 194: Peru RON 95 EX grade: Emissions of non-regulated parameters per ethanol blend

kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	1636497	1575947	1546490	1515396	1485939	1456482
VOC	127282	124658	123382	122035	120759	119482
VOC evap	17912	17912	17912	17912	17912	17912
NOx	81682	57177	53093	49009	44925	40841
SOx	612	435	396	358	319	280
NH3	8366	8282	8199	8115	8031	7948
Lead	0	0	0	0	0	0
Butadiene	68	68	67	67	67	67
Acetaldehydes	120	120	120	122	128	132
Formaldehydes	279	210	194	179	163	148
Benzene	3648	2181	1954	1745	1554	1371
CO2	41024533	36922080	36204150	35486221	34768292	34050362
N2O	608	608	602	601	599	596
CH4	29777	29777	29777	29777	29777	29777
PM 2.5	1845	1661	1421	1181	941	701
PM 10	693	624	534	444	354	263

Source: HCX

Figure 195: Peru RON 97 EX grade: Emissions of non-regulated parameters per ethanol blend

kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	1635927	1575397	1545951	1514868	1485421	1455975
VOC	127210	124588	123313	121966	120690	119415
VOC evap	17912	17912	17912	17912	17912	17912
NOx	81635	57145	53063	48981	44899	40818
SOx	586	417	380	343	305	268
NH3	8358	8274	8191	8107	8023	7940
Lead	0	0	0	0	0	0
Butadiene	68	67	67	67	67	67
Acetaldehydes	120	120	120	122	128	132
Formaldehydes	279	209	194	178	163	147
Benzene	4788	2862	2565	2291	2039	1799
CO2	41024533	36922080	36204150	35486221	34768292	34050362
N2O	604	604	598	597	595	592
CH4	29777	29777	29777	29777	29777	29777
PM 2.5	1845	1661	1421	1181	941	701
PM 10	693	624	534	444	354	263

Source: HCX

Graphs will not be included here as they are very similar to the graphs obtained from other gasoline grade.

Uruguay

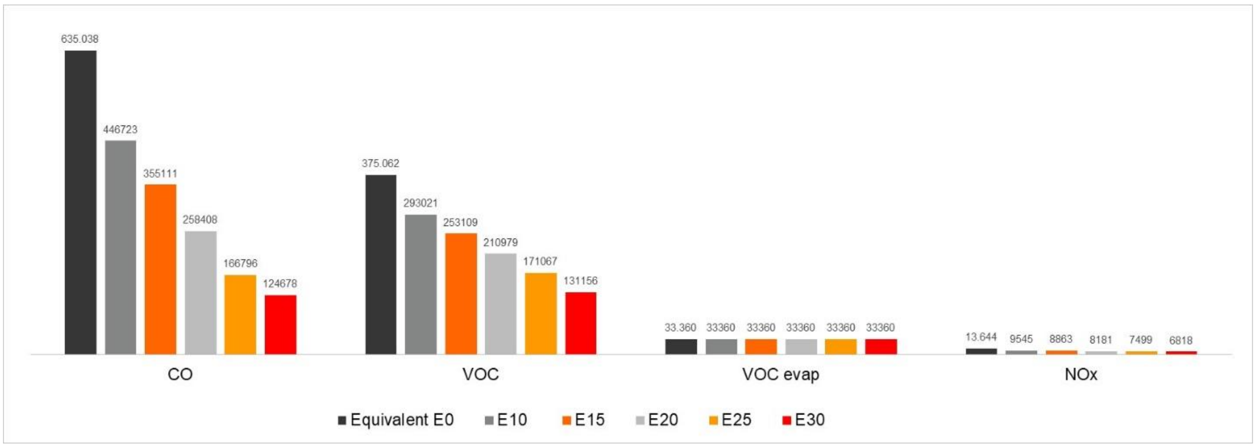
The emissions of the non-regulated parameters in kg per day are depicted below.

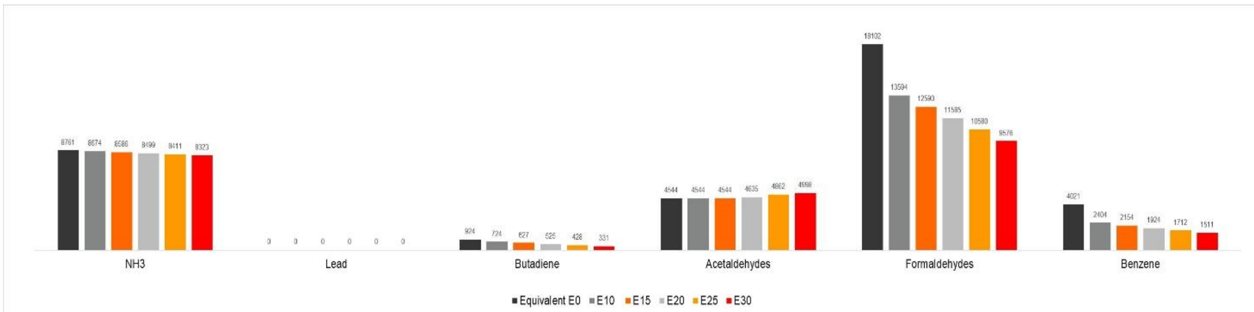
As observed, emissions that decreased with the addition of ethanol for the regular RON 91 and premium RON 95 gasoline grades are CO, VOC, NO_X, SO_X, NH_3, butadiene, formaldehydes, benzene, CO_2, N_2O, PM 2.5 and PM 10. Emissions of acetaldehydes increase as of E20. CO_2 emissions are much higher than other emissions.

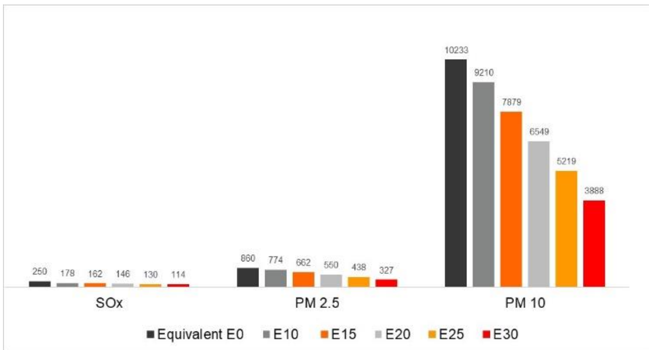
The difference of emissions between super and premium grades is benzene emissions.

Figure 196: Uruguay Super RON 95 EX and Premium RON 97 EX - Emissions of non-regulated parameters per ethanol blend

kg per day	Equivalent E0	E10	E15	E20	E25	E30
CO	635038	446723	355111	258408	166796	124678
VOC	375062	293021	253109	210979	171067	131156
VOC evap	33360	33360	33360	33360	33360	33360
NOx	13644	9545	8863	8181	7499	6818
SOx	250	178	162	146	130	114
NH3	8761	8674	8586	8499	8411	8323
Lead	0	0	0	0	0	0
Butadiene	924	724	627	525	428	331
Acetaldehydes	4544	4544	4544	4635	4862	4998
Formaldehydes	18102	13594	12590	11585	10580	9576
Benzene	4021	2404	2154	1924	1712	1511
CO2	20248268	18223441	17869096	17514752	17160407	16806062
N2O	184	184	182	182	181	180
CH4	78498	78498	78498	78498	78498	78498
PM 2.5	860	774	662	550	438	327
PM 10	10233	9210	7879	6549	5219	3888



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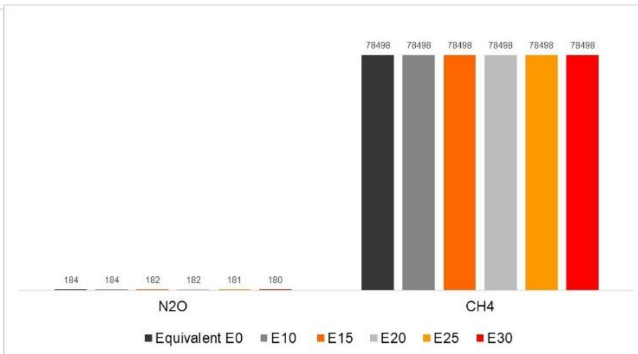
9210
7879
6549
5219
3888
250 178 162 146 130 114
860 774 662 550 438 327
SOx
PM 2.5
PM 10
Equivalent E0 E10 E15 E20 E25 E30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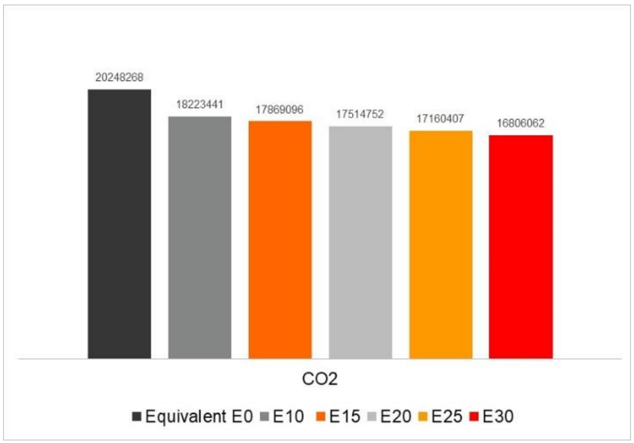
184 184 182 182 181 180
N2O
CH4
Equivalent E0 E10 E15 E20 E25 E30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17160407
16806062
CO2
Equivalent E0 E10 E15 E20 E25 E30

Source: HCX

SECTION 4: CASE STUDIES OF POTENTIAL IMPACT OF ETHANOL ON REGULATED PARAMETERS: CHILE, DR, GUATEMALA, PERU

SGS has performed analysis of gasoline and ethanol blends from four Latin American countries, with different gasoline qualities. The U.S. Grains Council has chosen to analyze samples of Chile, Dominican Republic, Guatemala, and Peru. The reasons to choose these countries are:

- Absence of ethanol: except for Peru, countries do not blend ethanol at the moment
- Regional representativeness: countries have different qualities and they can be representative to sub-regions in the continent
- Potential for higher blends: countries can potentially blend high ethanol blends, either because they have domestic ethanol production, or because their base gasoline can absorb high quantities of ethanol and still meet current specifications

SGS INSPIRE, with the help of SGS offices in the aforementioned countries, has collected samples of finished gasoline in fuel stations of Santiago, Santo Domingo, Guatemala City and Lima. Gasoline samples were transported to the laboratory of SGS in Speyer, Germany, and there they were splashed blended with ethanol meeting EU standard EN 15376 in increasing volumes (10%, 15%, 20%, 25% and 30%).

Ethanol-gasoline samples were then analyzed in the SGS laboratory. Results shown in this section are obtained with the purpose of illustrating the potential impact of ethanol blending in gasoline at increasing levels on regulated parameters: octane (RON and MON), sulfur, lead and other cations and anions, benzene, aromatics, olefins, paraffins, naphthenes, RVP, distillation points (T10, T50, T90, FBP, Residue), oxygen content, ethanol content, water volume, calorific value, air-fuel ratio and methyl-tert butyl ether (MTBE).

Results will show how ethanol blended with finished gasoline modifies values of selected parameters. However, in practice, if ethanol was blended with base gasoline (and not with finished gasoline), more benefits would be shown, as base gasoline characteristics would be optimized for the addition of ethanol. The finished product, an ethanol blend formed by optimized base gasoline and ethanol, would be more suited to embrace all benefits of ethanol blending and minimize the issues encountered with its blending. The differences between the optimized gasoline blendstock mix and finished gasoline are extensively described in Section 2.

The countries and the gasoline-ethanol blends are the following:

Figure 197: Ethanol blend grades selected per country

Country	Ethanol blends selected for analysis by U.S. Grains Council					
Chile (Santiago)	RON 95 E0	RON 95 E10	RON 95 E15	RON 95 E20	RON 95 E25	RON 95 E30
Dominican Republic (Santo Domingo)	RON 95 E0	RON 95 E10	RON 95 E15	RON 95 E20	RON 95 E25	RON 95 E30
Guatemala (Guatemala City)	RON 95 E0	RON 95 E10	RON 95 E15	RON 95 E20	RON 95 E25	RON 95 E30
Peru (Lima)	RON 90 E7.8	RON 90 E10	RON 90 E15	RON 90 E20	RON 90 E25	RON 90 E30

Source: SGS INSPIRE Compilation

Key Takeaways

Being an oxygenate, ethanol has a higher octane than gasoline, which means that blending ethanol into gasoline will increase the octane of the blend and displace the need of using other octane boosters as MTBE. The addition of oxygenates increases the total oxygen content of the blend, which should be below regulatory limits depending on the ethanol content.

The addition of ethanol to gasoline dilutes the blend, decreasing the content of sulfur and hydrocarbons (aromatics, paraffins, naphthenes, olefins, benzene), since ethanol does not contain either sulfur or hydrocarbons.

Distillation values is not affected by the addition of ethanol, as it is proved with the analysis performed. The calorific value and the air fuel ratio of the ethanol gasoline blend decrease, but this reduction is much lower than the content of ethanol added (i.e. 8-9% of calorific value and 11-12% of air fuel ratio decrease with the addition of 30% v/v ethanol).

Water is an important feature of the ethanol gasoline blend. According to ASTM D 4814 standard for Automotive Spark-Ignition Engine Fuel, a hydrocarbon-only fuel can dissolve up to 0.03% by mass of water, but hydrocarbon-alcohol blends can dissolve more water than exists at the time of blending and will provide protection against phase separation should small amounts of additional water contaminate the blended fuel as long as the blend’s temperature does not decrease. The level of improvement in water tolerance (the amount of water that can be dissolved before phase separation occurs) will increase with the concentration of alcohol in the fuel. For example, a 10% v/v ethanol blend with a typical hydrocarbon mixture at room temperature can dissolve up to 0.5% v/v water, as it is established by standard ASTM D 4814.

This information is also confirmed by the National Renewable Energy Laboratory (NREL) from the U.S., which states that an E10 blend can tolerate (exist as a single phase) over 0.4% v/v water at 15ºC (60ºF). Results from the analysis carried out by SGS indicate a much lower water content than tolerated by the ethanol blends studied up to E30.

Chile

Key Takeaways

The samples for the analysis of parameters are based on gasoline with RON 95 and 0% v/v ethanol content. RON 95 is produced by blending of RON 93 and RON 97. RON 95 had 28% of the market share in 2020. Ethanol is not used in Chile.

Chile uses MTBE for increasing octane. Analysis of samples indicate that BOB in Chile has a high quality. Choosing an adjusted blendstock mix prior to adding any oxygenate would help optimize the addition of ethanol to gasoline, also reduce the oxygen content in gasoline. Sulfur and hydrocarbons are reduced with the addition of ethanol as expected.

RVP increases significantly with the addition of 10% v/v ethanol and then it starts to decrease. Nevertheless, BOB' RVP is quite low, which would help meet specifications if ethanol was added. Water content increases with ethanol but not significantly.

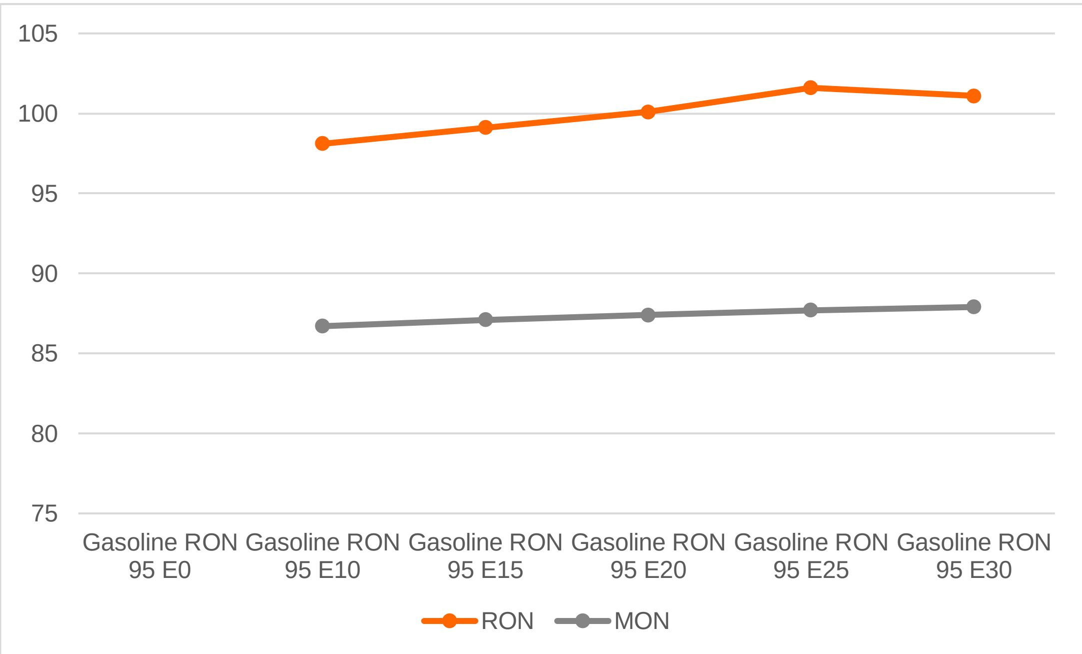
The addition of ethanol in gasoline does not affect distillation values of gasoline. The calorific value and the air-fuel ratio decrease but as expected, and do not affect the stability of the ethanol blend.

Octane

As can be seen below, Research Octane Number (RON) increases proportionally with the addition of ethanol. Motor Octane Number (MON) as well but remains more stable. Since the *before oxygenate blending* blendstock (BOB) has already a high RON 95, both because of the high BOB quality and the addition of MTBE, the addition of ethanol leads to an increase of RON up to 100. This octane high increase would be normally corrected through blendstock optimization, hence, using optimal blending components for addition of ethanol and without the addition of other oxygenates, such as MTBE.

It is interesting to notice that RON does not increase from E25 to E30.

Figure 198: RON and MON Values Gasoline + EtOH Samples

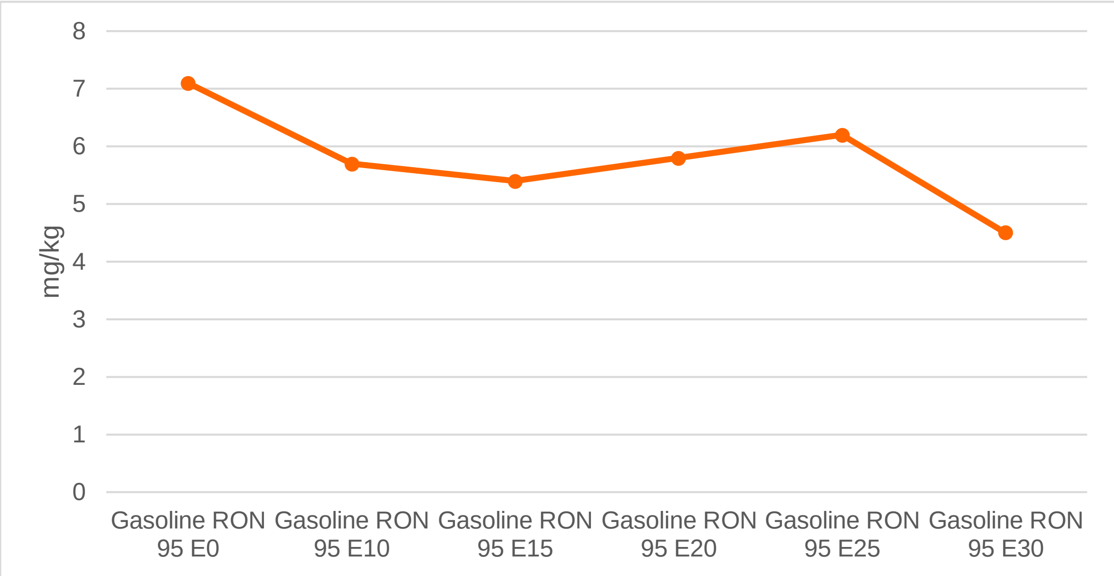


Source: SGS

Sulfur

Since ethanol does not contain any sulfur, the blending of ethanol in gasoline decreases the content of sulfur in the fuels, although this is not so relevant in Chile as gasoline contains already less than 10 mg/kg sulfur.

Figure 199: Sulfur (mg/kg) in Gasoline + EtOH Samples

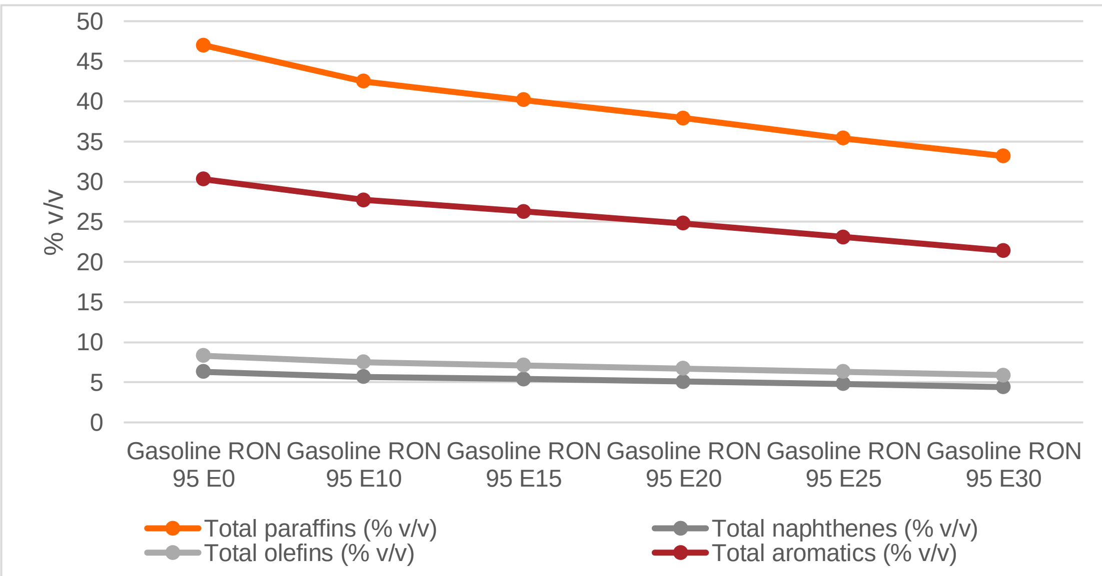


Source: SGS

Hydrocarbons

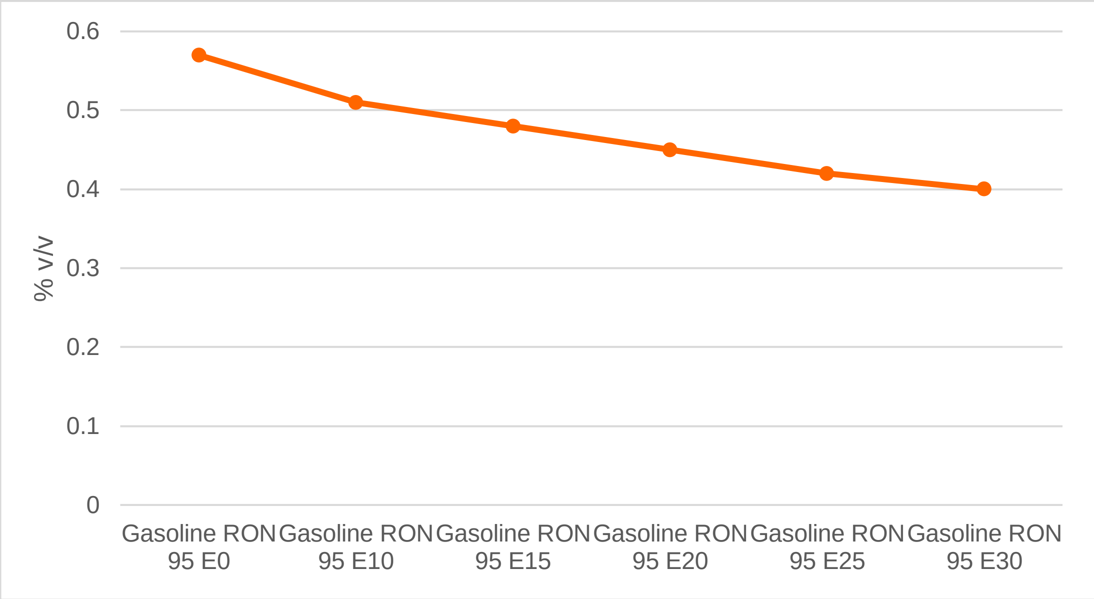
Since ethanol fuel does not contain hydrocarbons, the blending of ethanol in gasoline decreases the content of hydrocarbons in the fuel, particularly paraffins and aromatics.

Figure 200: Aromatics, Olefins, Paraffins and Naphthenes (% v/v) in Gasoline + EtOH Samples



Source: SGS

Figure 201: Benzene (% v/v) in Gasoline + EtOH Samples



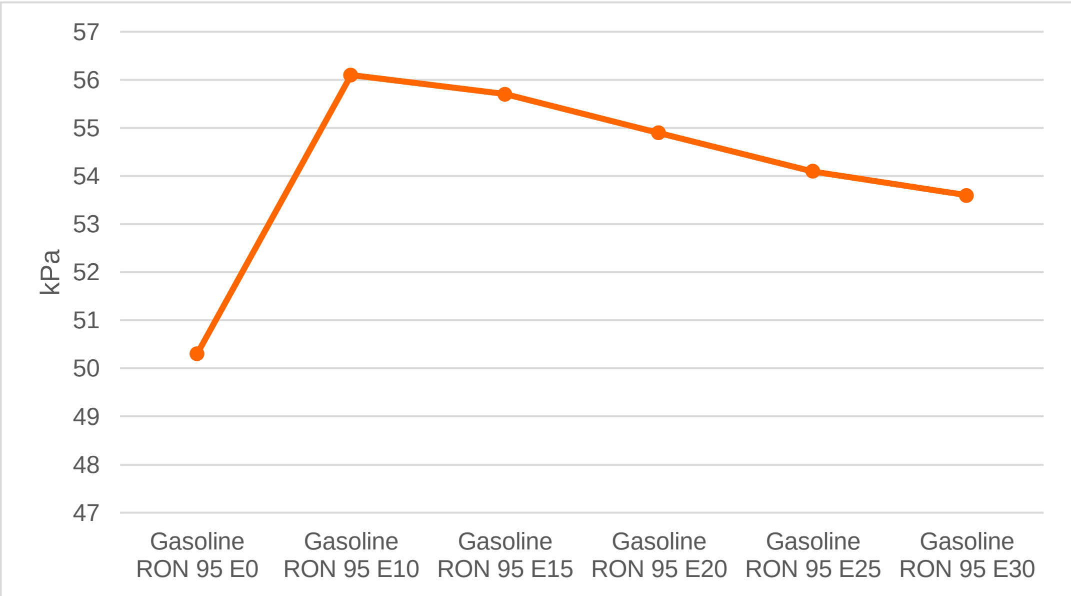
Source: SGS

Vapor Pressure (RVP)

According to the laboratory results, vapor pressure of gasoline starts increasing with the addition of ethanol in small quantities, it remains high until the ethanol reaches 10% v/v, when RVP starts decreasing. From E0 to E10, RVP increases 6 kPa.

It has to be noted that RVP from Chilean BOB is quite low. This factor may ease the addition of ethanol in gasoline because the final blend would comply with the regulatory limits.

Figure 202: RVP Values Gasoline + EtOH Samples (37.8ºC)



Source: SGS

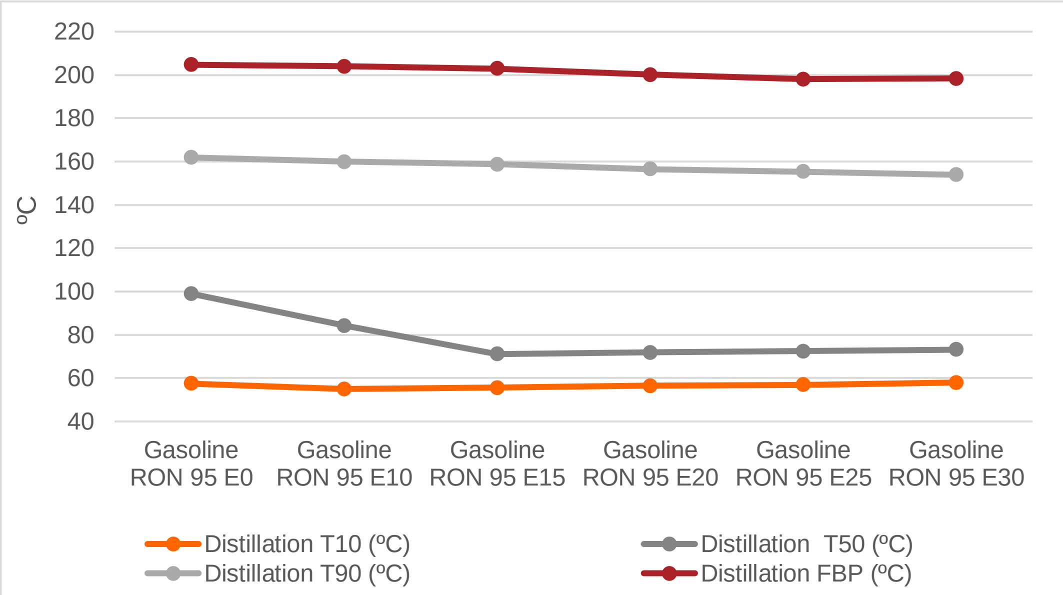
Distillation

The addition of ethanol led to small changes in the distillation curves; at low evaporated volumes, the lowest temperature is reached with 15% v/v ethanol content, but this temperature increases with the addition of ethanol. This is particularly observed for the temperature at 50% v/v evaporated.

The opposite behavior is observed at high evaporated volumes; temperature decreases when ethanol content increases.

In conclusion, ethanol blending into base RON 95 gasoline does not impact distillation significantly.

Figure 203: Distillation Evaporation Values (% v/v) in Gasoline + EtOH Samples



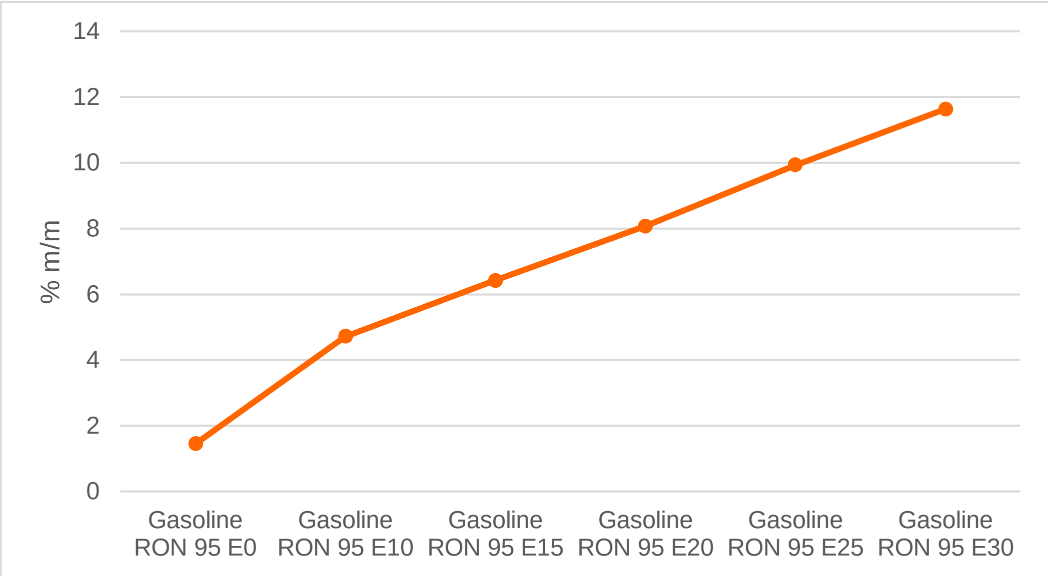
Source: SGS

Oxygen content and oxygenates

As observed below, the oxygen content increases proportionally with the addition of ethanol. The test method for total oxygenates does not evaluate oxygenates in amounts higher than 22% v/v and the ethanol content analyzed corresponds with the studied grades.

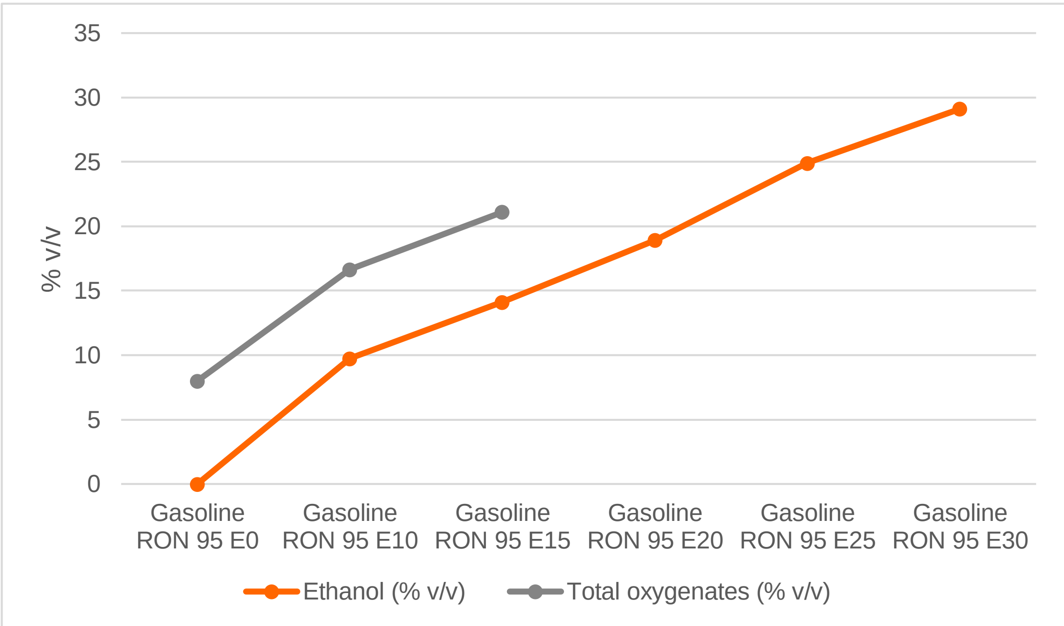
The MTBE content of E0 gasoline is close to 8% v/v. It dilutes when ethanol is added. If samples would have been formed of base gasoline and ethanol, without MTBE, oxygen content would not increase so much from E0 to E10 compared to E10 to E15, etc. and it would increase more linearly.

Figure 204: Oxygen content (% m/m) in Gasoline + EtOH Samples



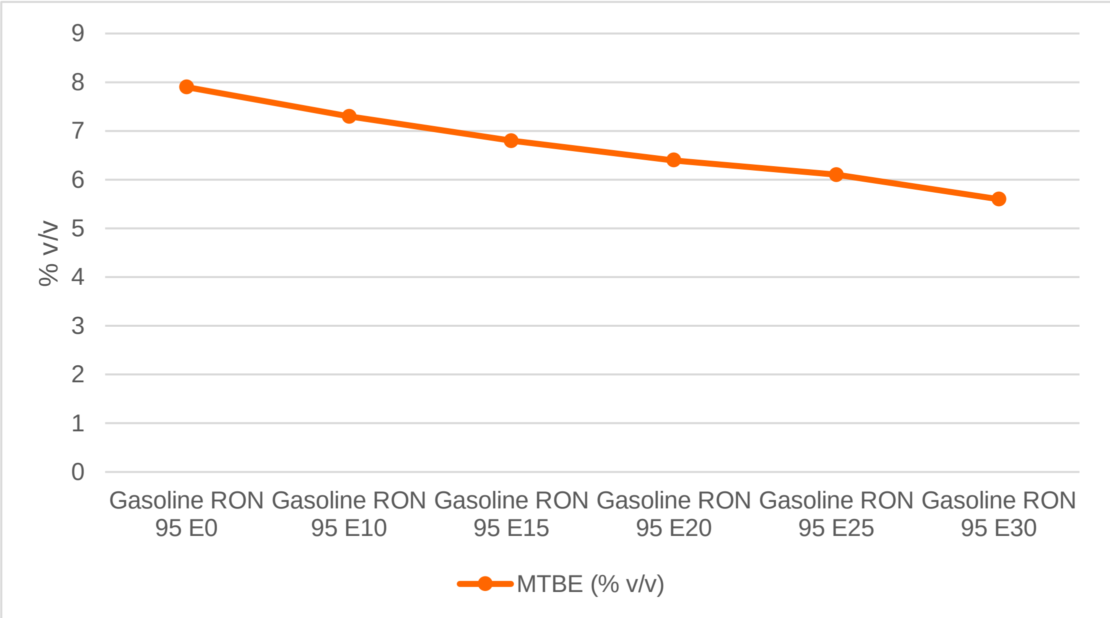
Source: SGS

Figure 205: Ethanol and total oxygenate content (% v/v) in Gasoline + EtOH Samples



Source: SGS

Figure 206: MTBE content (% v/v) in Gasoline + EtOH Samples

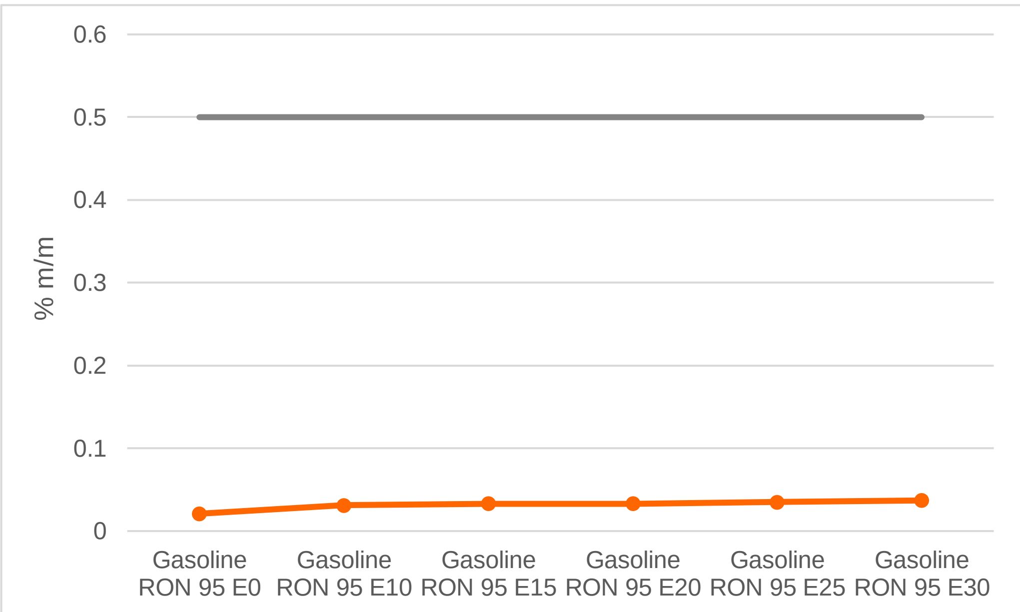


Source: SGS

Water content

The results show that the addition of ethanol on gasoline has a low impact on water content. The ethanol blends up to E30 have a water content significantly below the 0.5% v/v water content that can be dissolved in a 10% v/v ethanol blend with a typical hydrocarbon mixture at room temperature according to the ASTM D 4814 standard.

Figure 207: Water Content of Gasoline + EtOH Samples

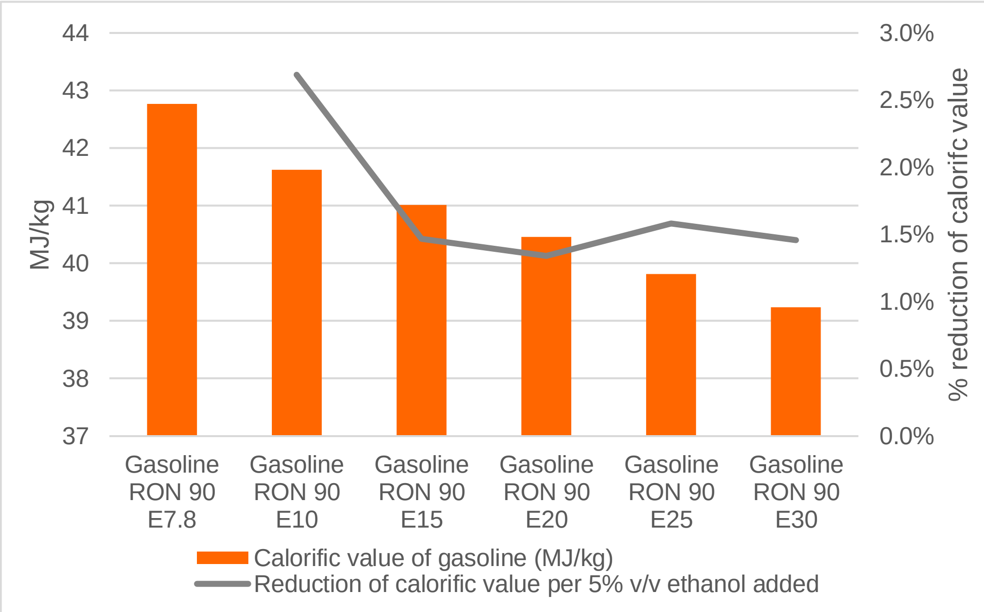


Source: SGS

Calorific Value

In the graph below it can be observed that the calorific value and ethanol have a linear relationship. Each 5% v/v of ethanol added decreases calorific value by 1.3-2.7% approximately.

Figure 208: Calorific Value of Gasoline + EtOH Samples

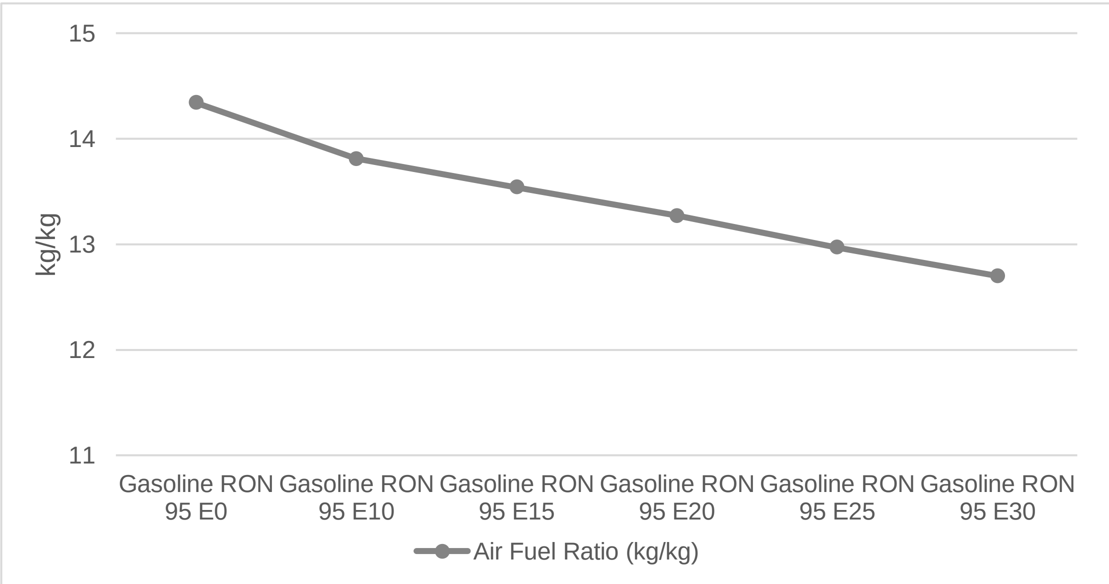


Source: SGS

Air-Fuel Ratio

In the graph below it can be observed that the air-fuel ratio and ethanol have a linear relationship, as for the calorific value. Each 5% v/v of ethanol added decreases air-fuel ratio by 0.3 kg/kg approximately.

Figure 209: Air-Fuel Ratio of Gasoline + EtOH Samples



Source: SGS

Other

The analysis of the samples shows no content of anions and cations: silicon, iron, aluminum, copper, lead, tin, chromium, nickel, zinc, phosphorous, magnesium, calcium, sodium, molybdenum, barium, potassium, titanium, vanadium, boron, manganese, silver, cobalt, and lithium.

Figure below summarizes values for all parameters studied for the gasoline grade and the ethanol blend grades.

Figure 210: Values for parameters for gasoline and ethanol grades in Chile

CHILE	Gasoline RON 95 E0	Gasoline RON 95 E10	Gasoline RON 95 E15	Gasoline RON 95 E20	Gasoline RON 95 E25	Gasoline RON 95 E30
RON		98.1	99.1	100.1	101.6	101.1
MON		86.7	87.1	87.4	87.7	87.9
Water Content (% m/m)	0.021	0.031	0.033	0.033	0.035	0.037
RVP (kPa)	50.3	56.1	55.7	54.9	54.1	53.6
Sulfur (mg/kg)	7.1	5.7	5.4	5.8	6.2	4.5
Oxygen content (% m/m)	1.44	4.71	6.41	8.07	9.93	11.63
Ethanol (% v/v)	0	9.75	14.12	18.91	24.91	29.11
Total oxygenates (% v/v)	8	16.66	21.1	N/A	N/A	N/A
Total paraffins (% v/v)	47	42.5	40.2	37.9	35.4	33.2
Total naphthenes (% v/v)	6.3	5.7	5.4	5.1	4.8	4.4
Total olefins (% v/v)	8.3	7.5	7.1	6.7	6.3	5.9
Total aromatics (% v/v)	30.3	27.7	26.3	24.8	23.1	21.4
MTBE (% v/v)	7.9	7.3	6.8	6.4	6.1	5.6
Benzene (% v/v)	0.57	0.51	0.48	0.45	0.42	0.4
Cations and anions (mg/kg)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Distillation T10 (ºC)	57.5	55	55.6	56.5	56.9	58
Distillation T50 (ºC)	99	84.3	71.1	71.9	72.4	73.2
Distillation T90 (ºC)	161.9	159.9	158.7	156.6	155.4	153.9

Distillation FBP (ºC)	204.7	204	202.9	200.1	198.1	198.4
Distillation residue (% v/v)	1	1	1	1	1	1
Calorific value of gasoline (MJ/kg)	42.77	41.62	41.01	40.46	39.82	39.24
Air Fuel Ratio (kg/kg)	14.34	13.81	13.54	13.27	12.97	12.7

Source: SGS

Dominican Republic

Key Takeaways

The samples for the analysis of parameters are based on gasoline with RON 95 and 0% v/v ethanol content. This is the premium grade and its market share is 62%. The other grade in the market, the regular grade, has a RON of 89. Ethanol is not used yet in Dominican Republic.

The premium grade already has an RON of 95 without ethanol or any other oxygenate. If ethanol would be added, less blending components that are added to increase octane would be required. Furthermore, the oxygen limit of E10 also would meet European specifications. Sulfur and hydrocarbons are reduced with the addition of ethanol as expected. Particularly for aromatics, the addition of ethanol would help the country get closer to the European regulatory limits.

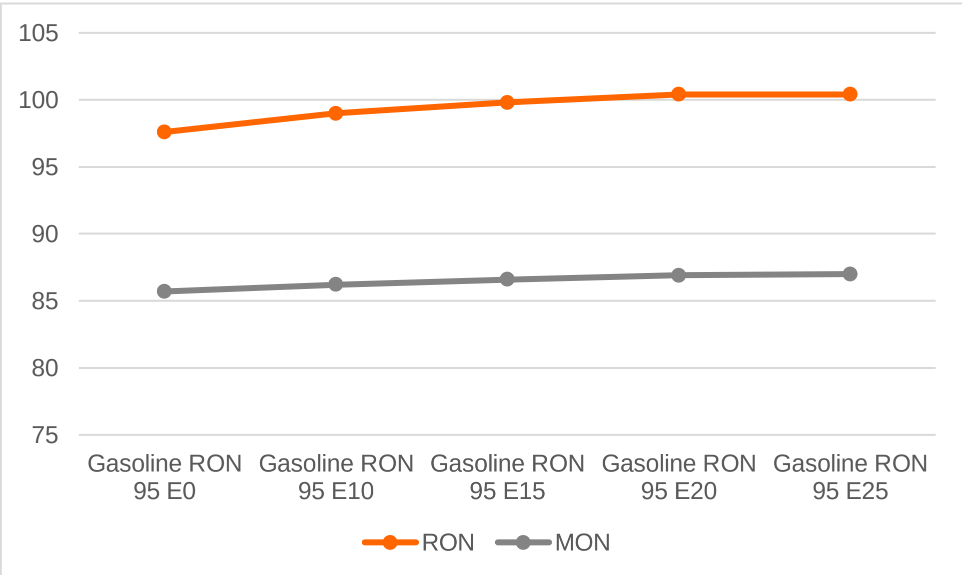
RVP increases significantly with the addition of 10% v/v ethanol and then it starts to decrease. Nevertheless, based BOB' RVP is quite low, which would help meet specifications if ethanol is added. Water content increases with ethanol but not significantly.

The addition of ethanol in gasoline does not affect distillation values of gasoline. The calorific value and the air-fuel ratio decrease but as expected, and do not affect the stability of the ethanol blend.

Octane

As can be seen below, Research Octane Number (RON) increases proportionally with the addition of ethanol. Motor Octane Number (MON) as well but remains more stable. Since the *before oxygenate blending* blendstock (BOB) has already a high RON 95, the addition of ethanol leads to an increase of RON up to 100. It is interesting to notice that RON does not increase from E25 to E30.

Figure 211: RON and MON Values Gasoline + EtOH Samples

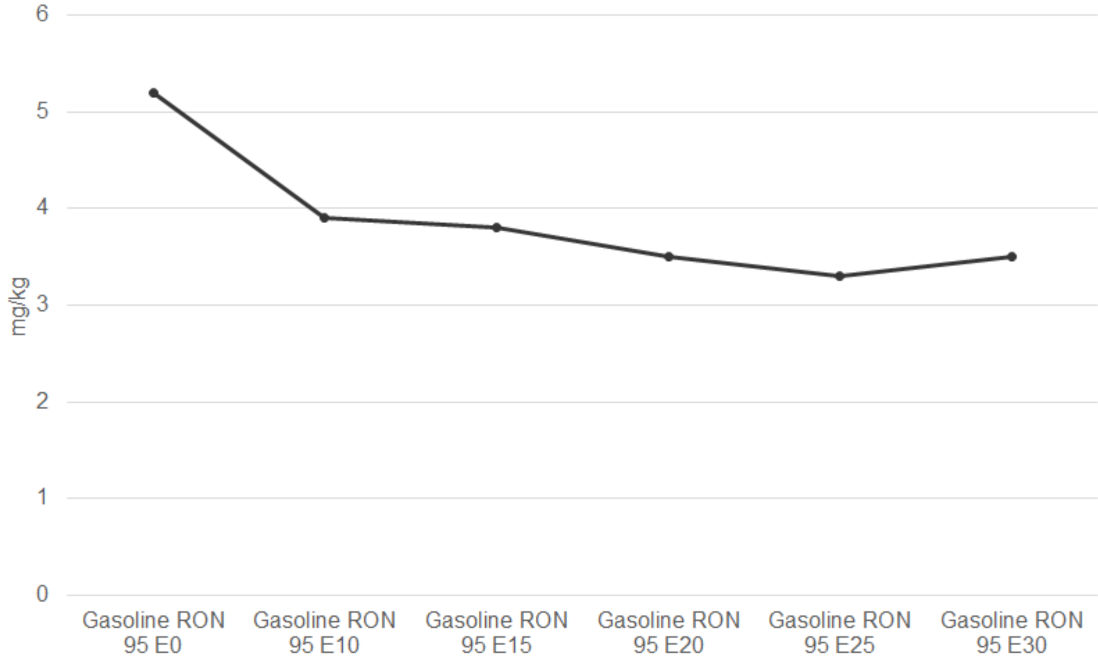


Source: SGS

Sulfur

Since ethanol does not contain any sulfur, the blending of ethanol in gasoline decreases the content of sulfur in the fuels, as can be seen in the graph below.

Figure 212: Sulfur (mg/kg) in Gasoline + EtOH Samples

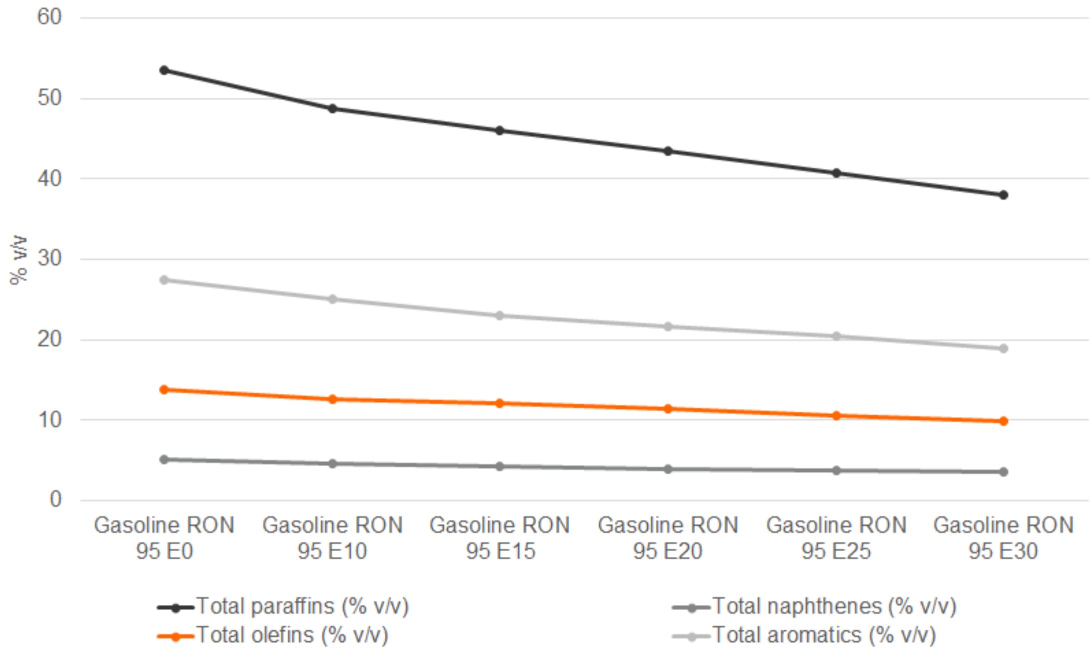


Source: SGS

Hydrocarbons

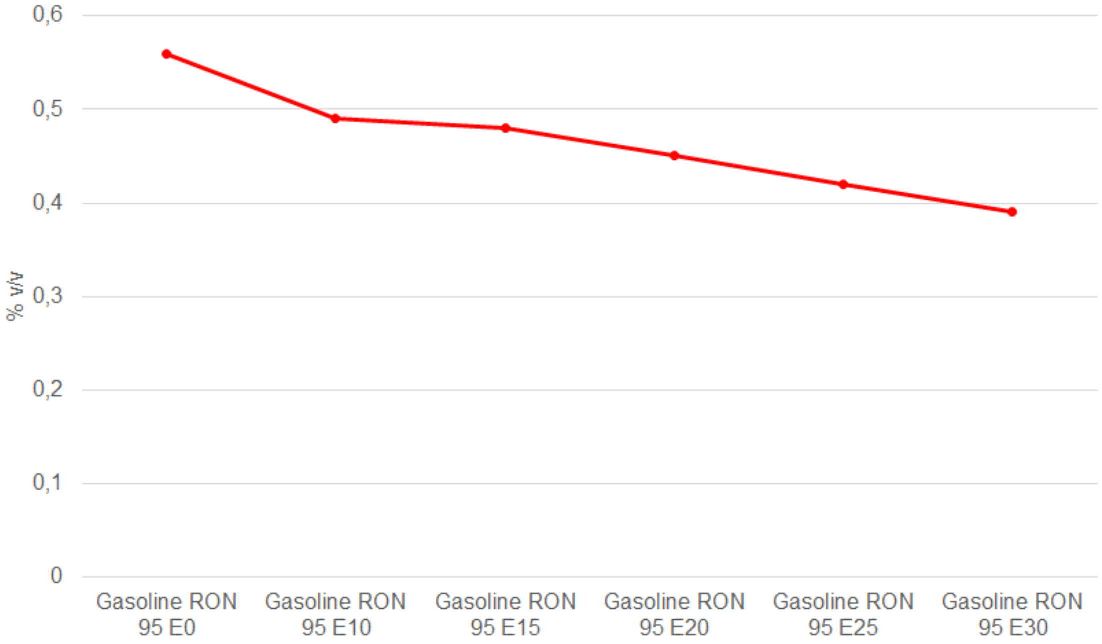
Since ethanol fuel does not contain hydrocarbons, the blending of ethanol in gasoline decreases the content of hydrocarbons in the fuel, particularly paraffins and aromatics.

Figure 213: Aromatics, Olefins, Paraffins and Naphthenes (% v/v) in Gasoline + EtOH Samples



Source: SGS

Figure 214: Benzene (% v/v) in Gasoline + EtOH Samples

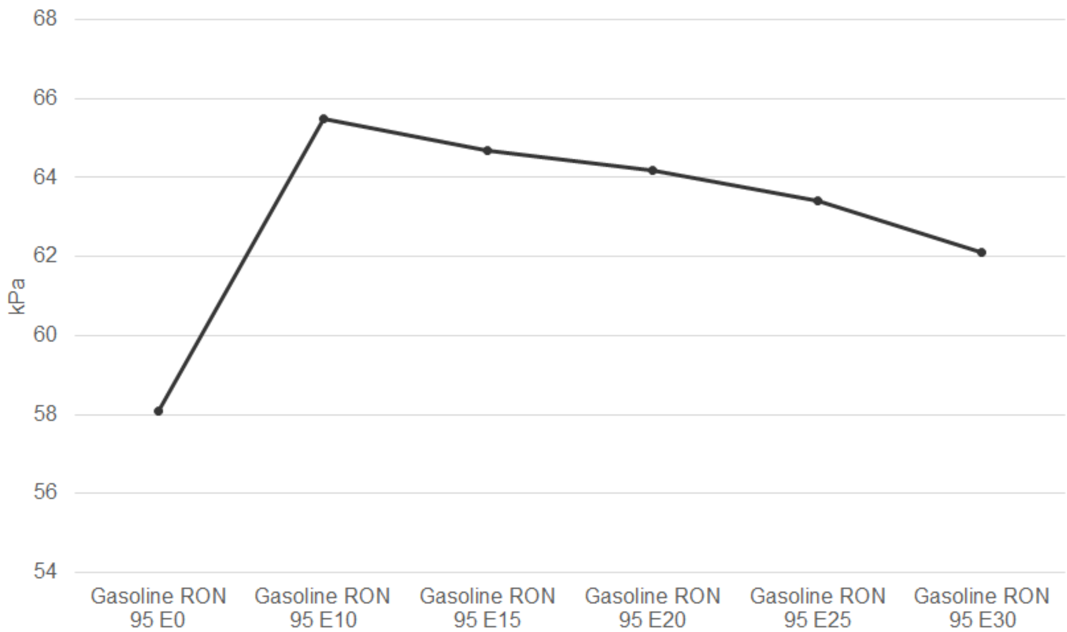


Source: SGS

Vapor Pressure (RVP)

According to the laboratory results, vapor pressure of gasoline starts increasing with the addition of ethanol in small quantities, it remains high until the ethanol reaches 10% v/v, when RVP starts decreasing. From E0 to E10, RVP increases almost 8 kPa. After the addition of 25% v/v ethanol, the RVP decrease is more pronounced.

Figure 215: RVP Values Gasoline + EtOH Samples (37.8ºC)

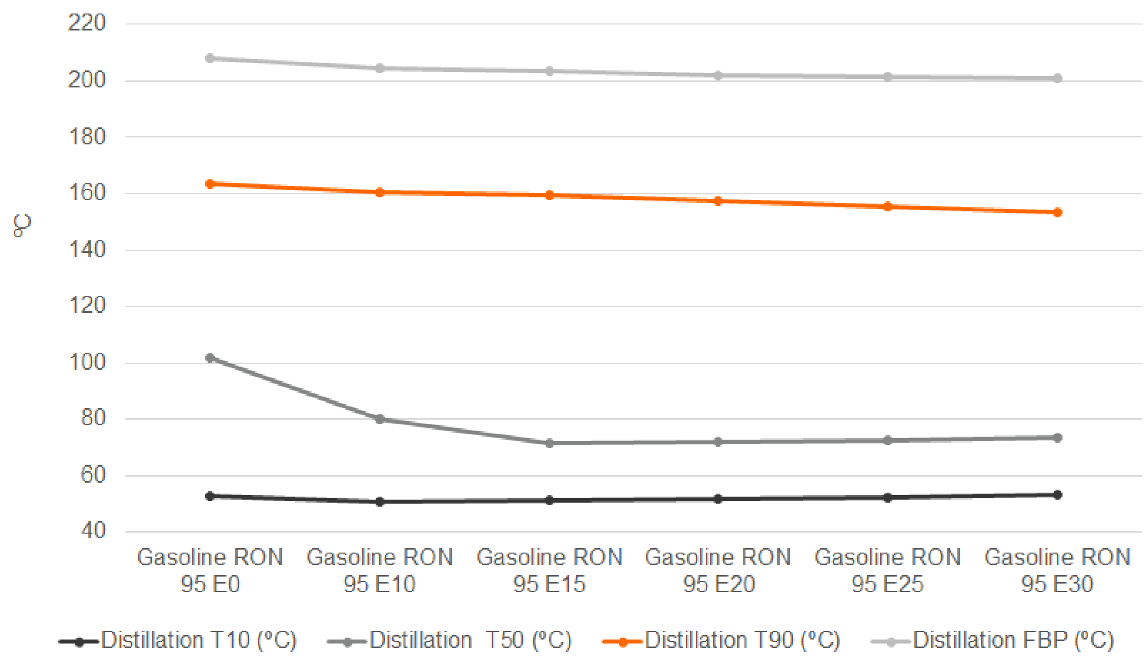


Source: SGS

Distillation

The addition of ethanol led to small changes in the distillation curves. The most significant change is seen for temperature at distillation evaporated for 50% v/v. From E0 to E15, the temperature values decrease significant to grow again after more than 15% v/v is added to gasoline. In conclusion, ethanol addition to gasoline does not impact distillation values significantly.

Figure 216: Distillation Evaporation Values (% v/v) in Gasoline + EtOH Samples

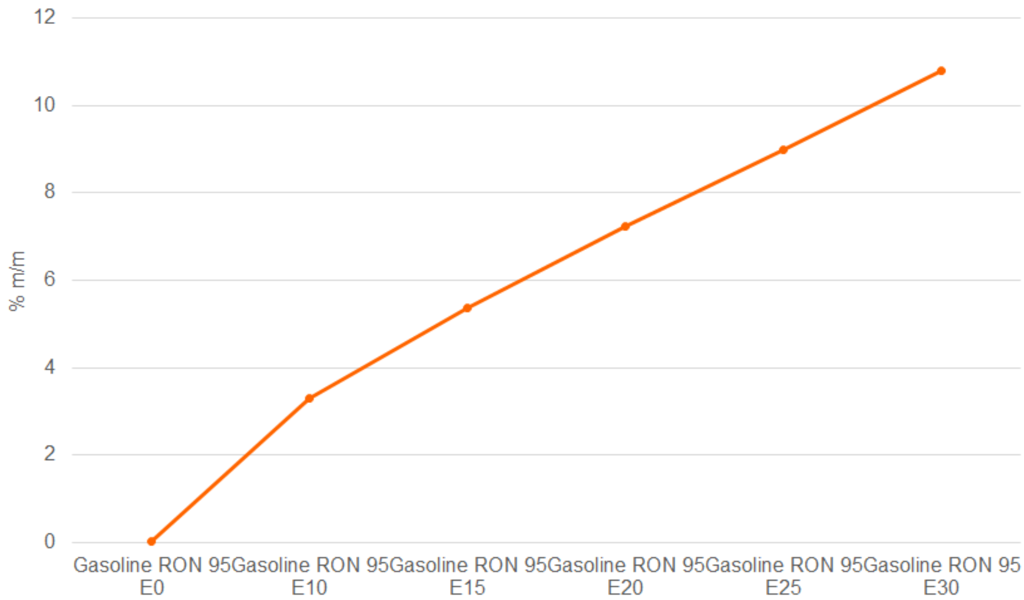


Source: SGS

Ethanol and oxygen content

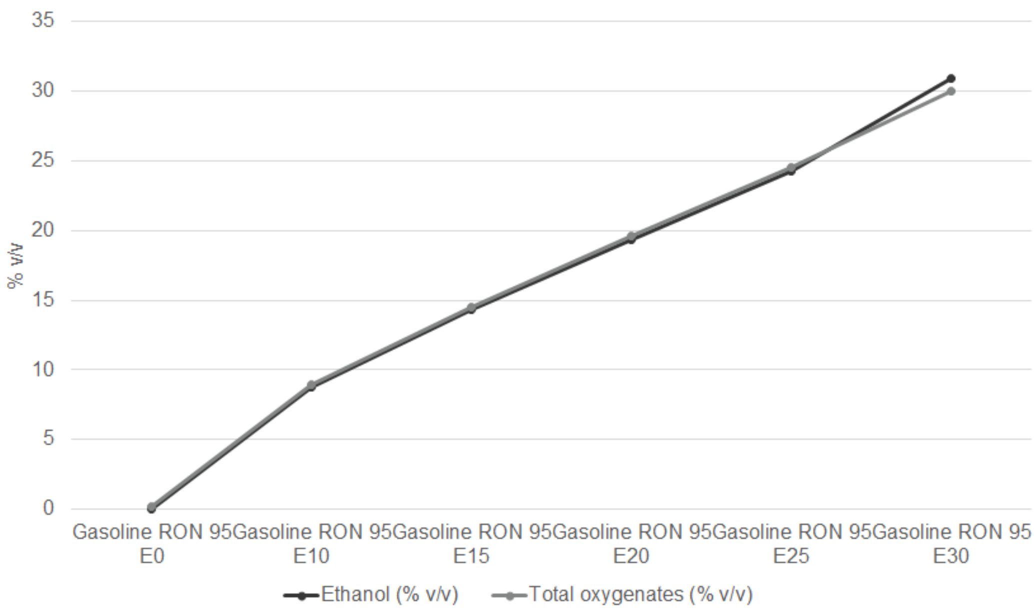
As observed below, the oxygen content increases proportionally with the addition of ethanol.

Figure 217: Oxygen content (% m/m) in Gasoline + EtOH Samples



Source: SGS

Figure 218: Ethanol and total oxygenate content (% v/v) in Gasoline + EtOH Samples

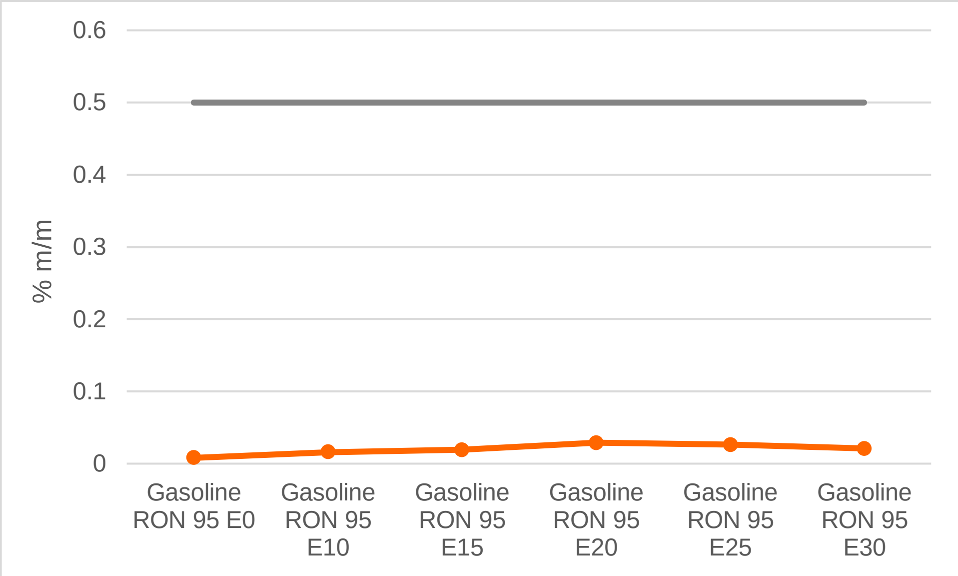


Source: SGS

Water content

The results show that the addition of ethanol on gasoline has a low impact on water content. The ethanol blends up to E30 have a water content significantly below the 0.5% v/v water content that can be dissolved in a 10% v/v ethanol blend with a typical hydrocarbon mixture at room temperature according to the ASTM D 4814 standard.

Figure 219: Water Content of Gasoline + EtOH Samples

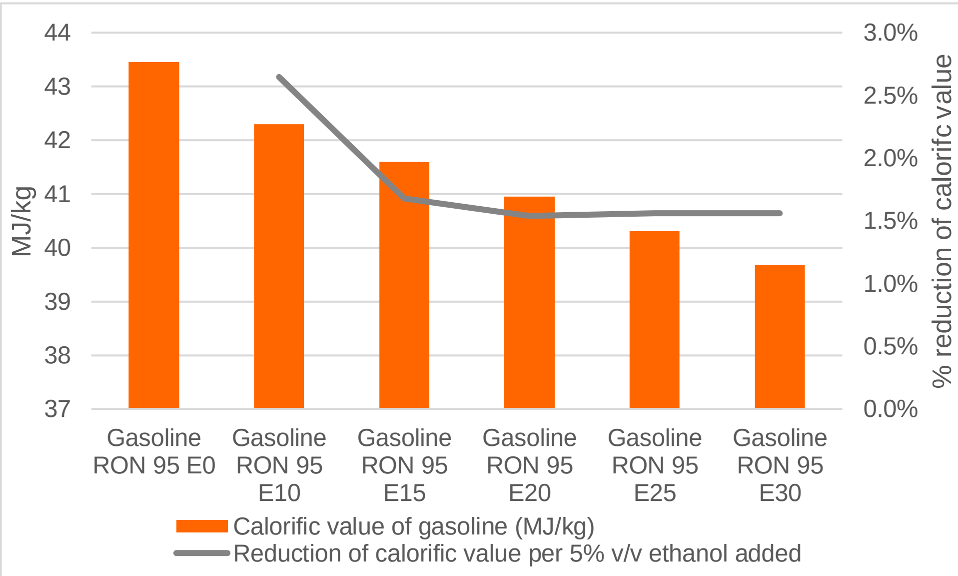


Source: SGS

Calorific Value

In the graph below it can be observed that the calorific value and ethanol have a linear relationship. Each 5% v/v of ethanol added decreases calorific value by 1.5-2.6% approximately.

Figure 220: Calorific Value of Gasoline + EtOH Samples

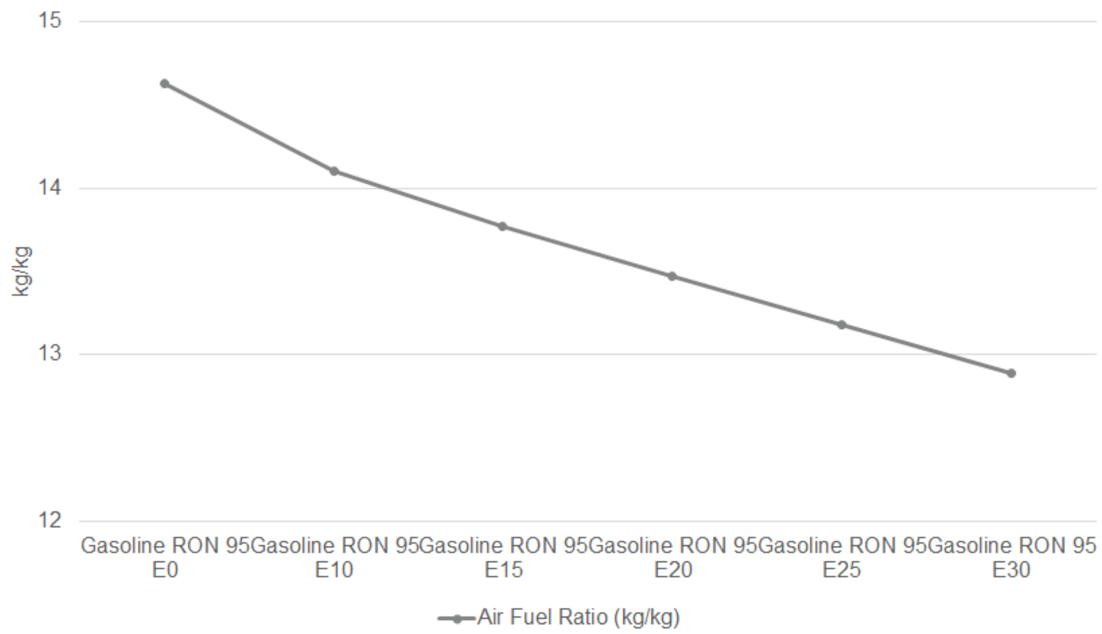


Source: SGS

Air-Fuel Ratio

In the graph below it can be observed that the air-fuel ratio and ethanol have a linear relationship, as for the calorific value. Each 5% v/v of ethanol added decreases air-fuel ratio 0.3 kg/kg approximately.

Figure 221: Air-Fuel Ratio of Gasoline + EtOH Samples



Source: SGS

Other

The analysis of the samples shows no content of MTBE and anions and cations: silicon, iron, aluminum, copper, lead, tin, chromium, nickel, zinc, phosphorous, magnesium, calcium, sodium, molybdenum, barium, potassium, titanium, vanadium, boron, manganese, silver, cobalt and lithium.

Figure below summarizes values for all parameters studied for the gasoline grade and the ethanol blend grades.

Figure 222: Values for parameters for gasoline and ethanol grades in Dominican Republic

	Gasoline RON 95 E0	Gasoline RON 95 E10	Gasoline RON 95 E15	Gasoline RON 95 E20	Gasoline RON 95 E25	Gasoline RON 95 E30
RON		97.6	99	99.8	100.4	100.4
MON		85.7	86.2	86.6	86.9	87
Water Content (% m/m)	0.008	0.016	0.019	0.029	0.026	0.021
RVP (kPa)	58.1	65.5	64.7	64.2	63.4	62.1
Sulfur (mg/kg)	5.2	3.9	3.8	3.5	3.3	3.5
Oxygen content (% m/m)	0.03	3.31	5.38	7.23	9	10.81
Ethanol (% v/v)	0	8.81	14.36	19.37	24.24	30.88
Total oxygenates (% v/v)	0.2	8.93	14.55	19.62	24.52	30

Total paraffins (% v/v)	53.6	48.7	46.1	43.4	40.7	38
Total naphthenes (% v/v)	5.1	4.6	4.3	4	3.8	3.6
Total olefins (% v/v)	13.8	12.7	12.1	11.4	10.6	9.9
Total aromatics (% v/v)	27.4	25.1	23	21.6	20.4	19
MTBE (% v/v)	0	0	0	0	0	0
Benzene (% v/v)	0.56	0.49	0.48	0.45	0.42	0.39
Cations and anions (mg/kg)	0	0	0	0	0	0
Distillation T10 (ºC)	52.8	50.5	51.3	51.7	52.3	53.4
Distillation T50 (ºC)	101.7	80.2	71.3	71.8	72.6	73.6
Distillation T90 (ºC)	163.7	160.6	159.7	157.2	155.6	153.5
Distillation FBP (ºC)	208.1	204.7	203.4	202	201.4	201.2
Distillation residue (% v/v)	1.1	1.1	1	1.1	1.1	1
Calorific value of gasoline (MJ/kg)	43.45	42.3	41.59	40.95	40.31	39.68
Air Fuel Ratio (kg/kg)	14.63	14.1	13.77	13.47	13.18	12.89

Source: SGS

Guatemala

Key Takeaways

The samples for the analysis of parameters are based on gasoline with RON 95 and 0% v/v ethanol content. RON 95 is the premium grade in Guatemala and had 48% of the market share in 2020.

Octane in the premium grade in Guatemala is already at RON 95. The addition of ethanol increases it up to almost 100, but it does not increase further with the addition of more ethanol. Sulfur and hydrocarbons are reduced with the addition of ethanol as expected. In the case of sulfur, aromatics and olefins, Peru would be closer to meet EU specifications if ethanol content in gasoline would be higher.

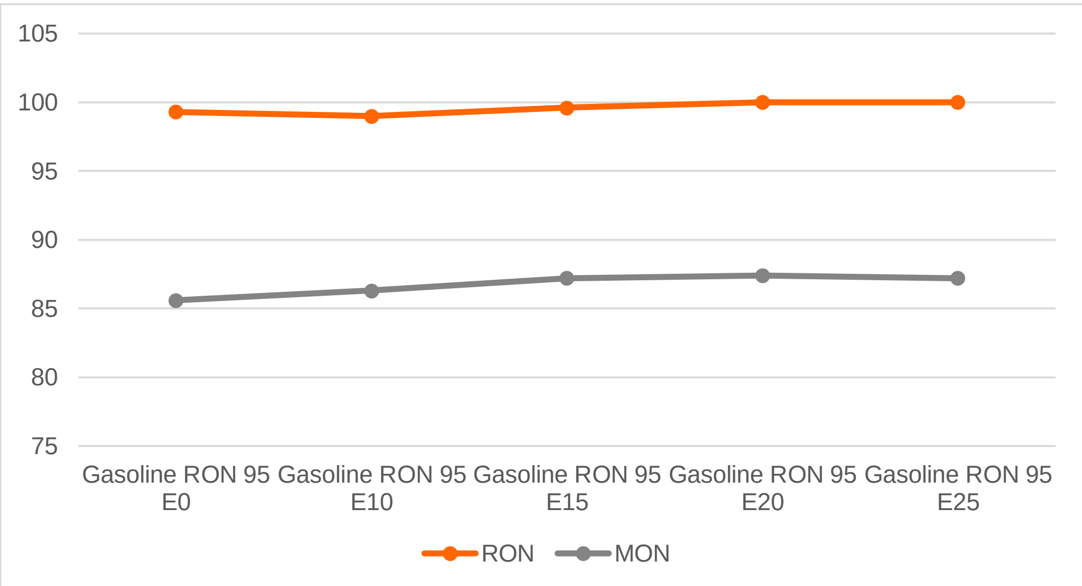
According to the laboratory results, vapor pressure of gasoline starts increasing with the addition of ethanol in small quantities, it remains high until the ethanol reaches 10% v/v, when RVP starts decreasing. From E0 to E10, RVP increases 7 kPa, a very pronounced growth. Only with the addition of 25% v/v ethanol, RVP is below EU regulatory limits (69 kPa). Therefore, the BOB should be modified so that components don´t increase RVP so much with the addition of ethanol.

The addition of ethanol in gasoline does not affect distillation values of gasoline. The calorific value and the air-fuel ratio decrease but as expected, and do not affect the stability of the ethanol blend.

Octane

As can be seen below, Research Octane Number (RON) increases proportionally with the addition of 10% v/v ethanol. Motor Octane Number (MON) increases as well. It is remarkable to note that octane does not increase significantly with the addition of ethanol from 10% v/v to 30% v/v.

Figure 223: RON and MON Values Gasoline + EtOH Samples

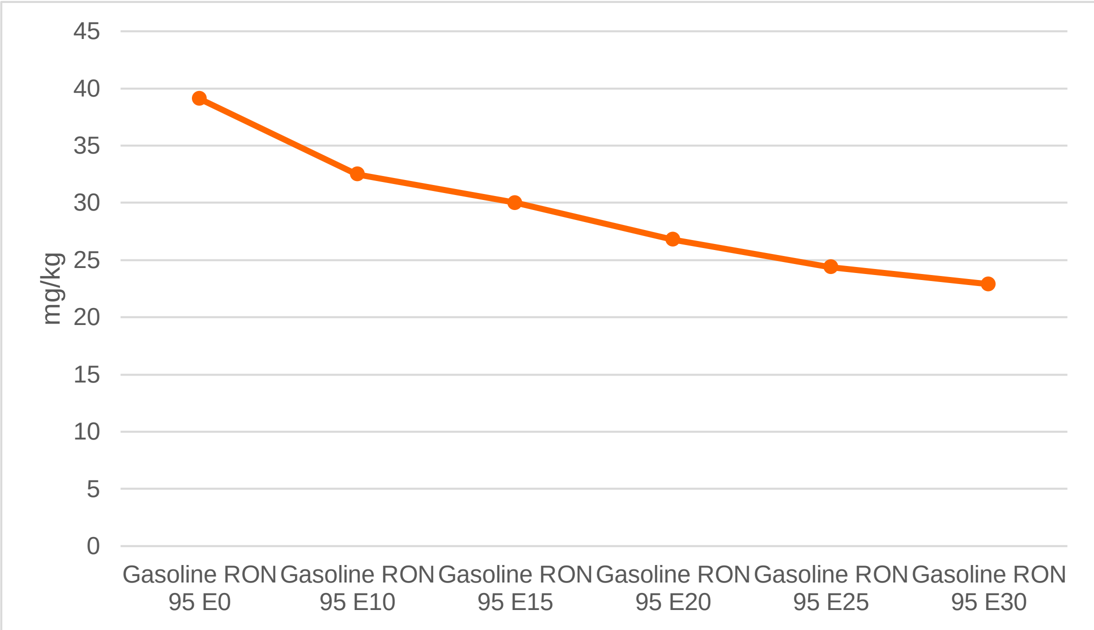


Source: SGS

Sulfur

Since ethanol does not contain any sulfur, the blending of ethanol in gasoline decreases the content of sulfur in the fuels. From E0 to E30, sulfur is reduced by 16 mg/kg.

Figure 224: Sulfur (mg/kg) in Gasoline + EtOH Samples

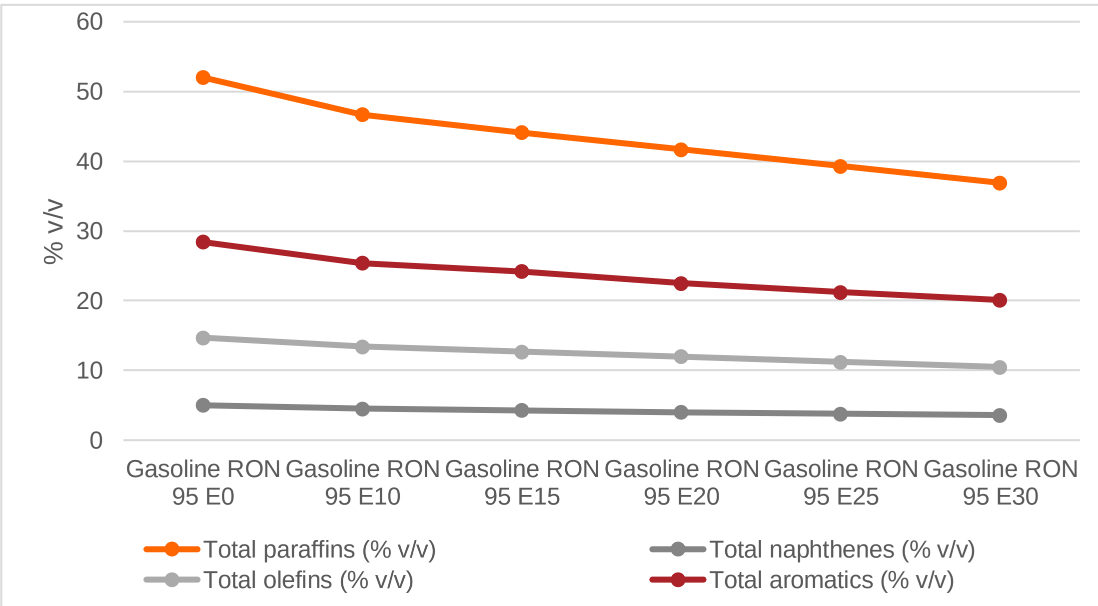


Source: SGS

Hydrocarbons

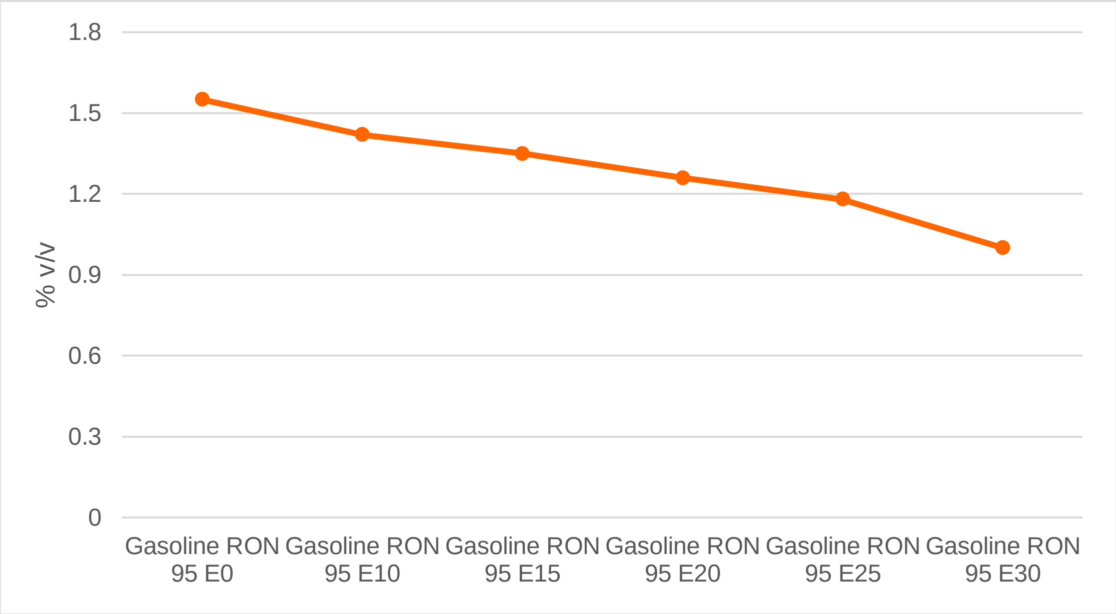
Since ethanol fuel does not contain hydrocarbons, the blending of ethanol in gasoline decreases the content of hydrocarbons in the fuel, particularly paraffins and aromatics.

Figure 225: Aromatics, Olefins, Paraffins and Naphthenes (% v/v) in Gasoline + EtOH Samples



Source: SGS

Figure 226: Benzene (% v/v) in Gasoline + EtOH Samples



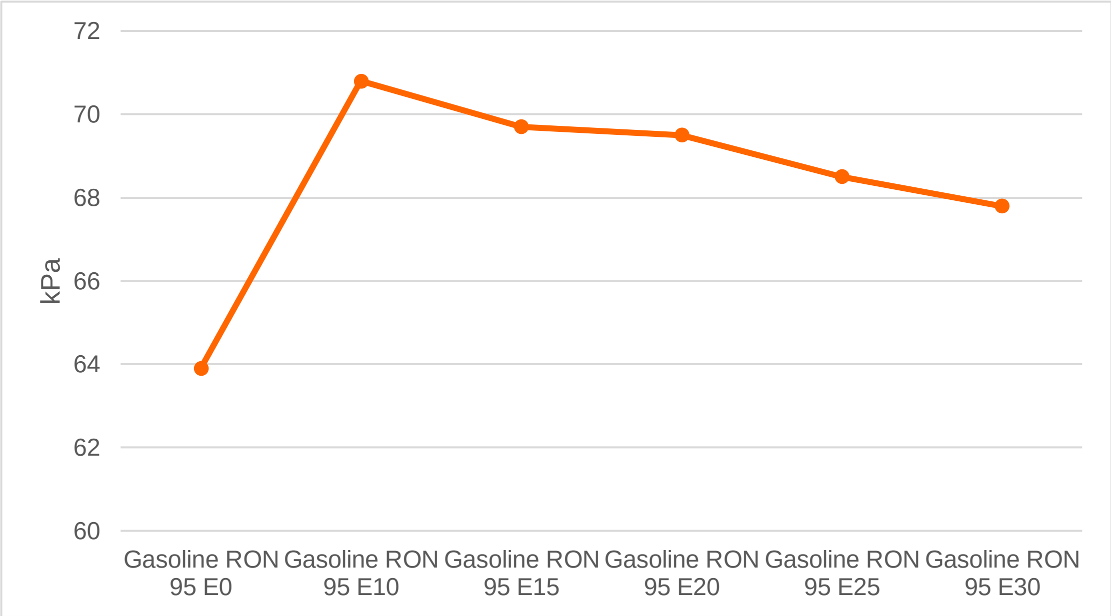
Source: SGS

Vapor Pressure (RVP)

According to the laboratory results, vapor pressure of gasoline starts increasing with the addition of ethanol in small quantities, it remains high until the ethanol reaches 10% v/v, when RVP starts decreasing. From E0 to E10, RVP increases 7 kPa, a very pronounced growth. Only with the addition of 25% v/v ethanol, RVP is below EU regulatory limits (69 kPa). Therefore, the BOB should be modified so that components don´t increase RVP so much with the addition of ethanol.

After the addition of 25% v/v ethanol, the RVP decrease is less pronounced.

Figure 227: RVP Values Gasoline + EtOH Samples (37.8ºC)

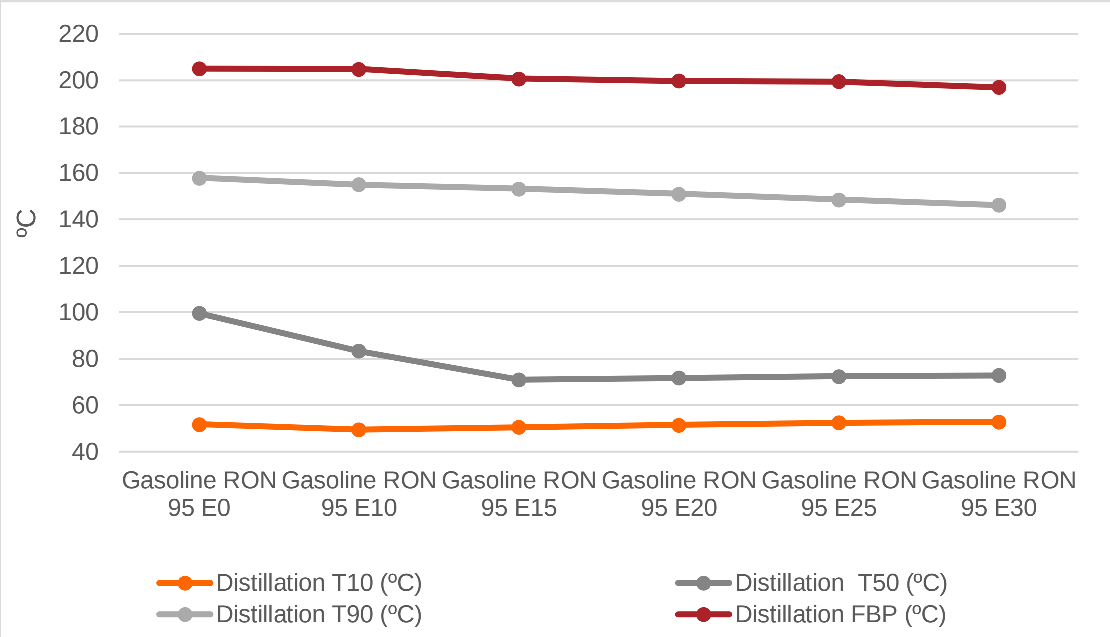


Source: SGS

Distillation

The addition of ethanol led to small changes in the distillation curves. It can be concluded that ethanol does not have a significant impact on distillation.

Figure 228: Distillation Evaporation Values (% v/v) in Gasoline + EtOH Samples

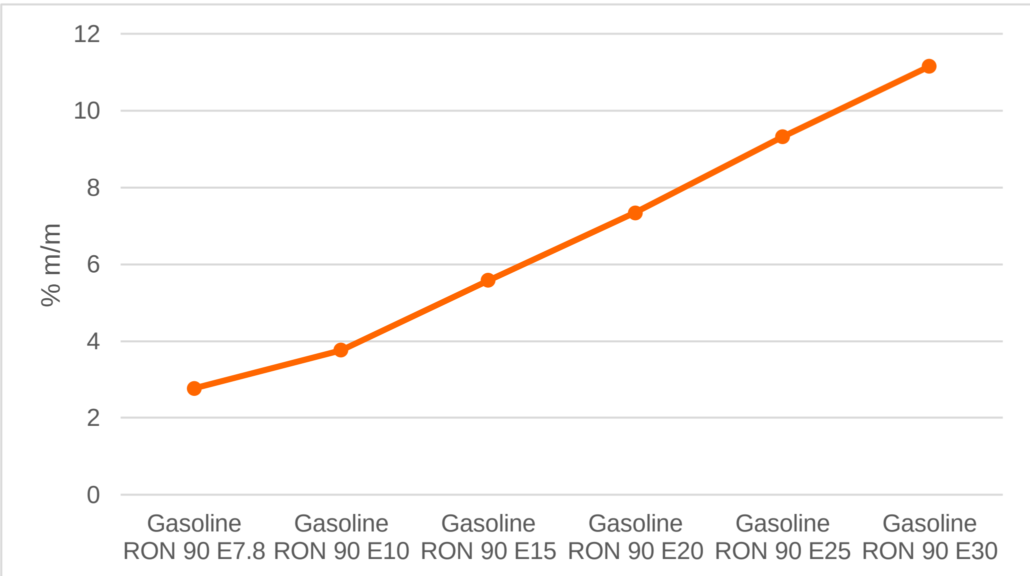


Source: SGS

Ethanol and oxygen content

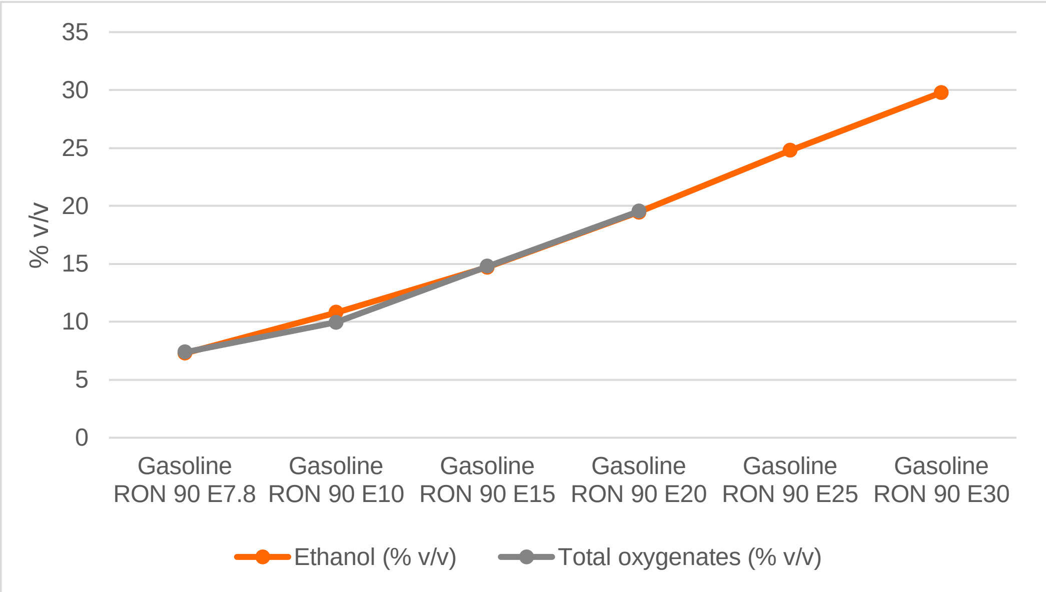
As observed below, the oxygen content increases proportionally with the addition of ethanol.

Figure 229: Oxygen content (% m/m) in Gasoline + EtOH Samples



Source: SGS

Figure 230: Ethanol and total oxygenate content (% v/v) in Gasoline + EtOH Samples

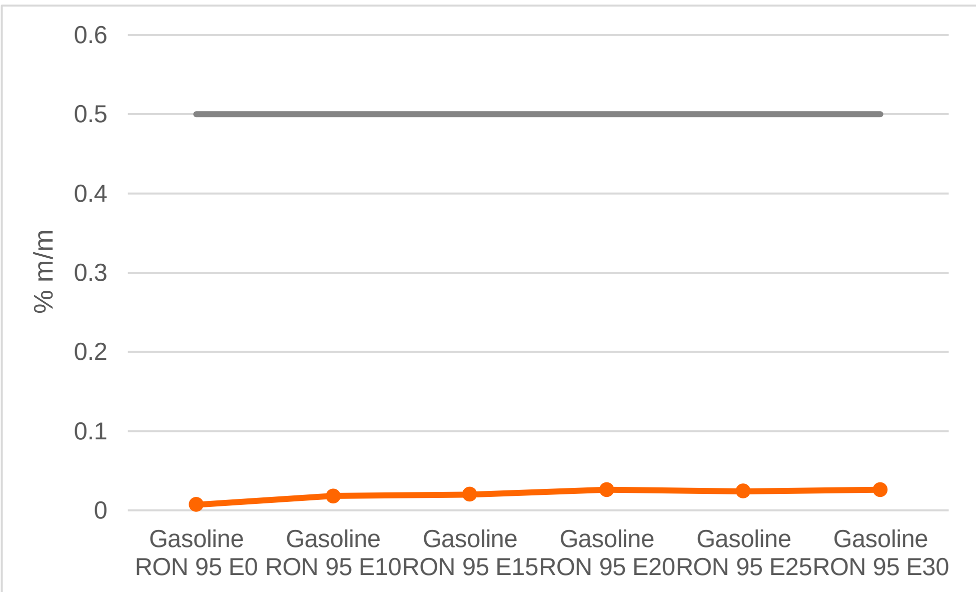


Source: SGS

Water content

The results show that the addition of ethanol on gasoline has a low impact on water content. The ethanol blends up to E30 have a water content significantly below the 0.5% v/v water content that can be dissolved in a 10% v/v ethanol blend with a typical hydrocarbon mixture at room temperature according to the ASTM D 4814 standard.

Figure 231: Water Content of Gasoline + EtOH Samples

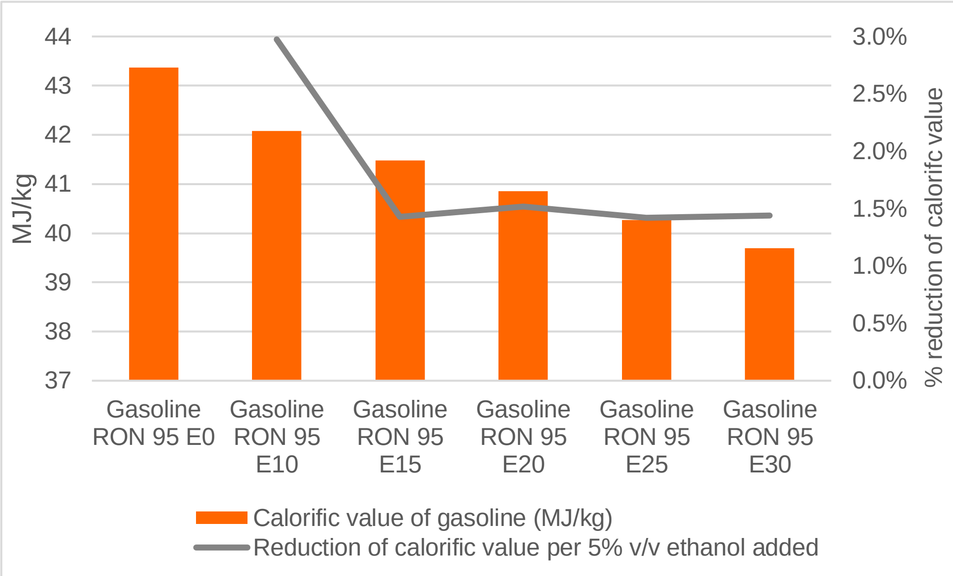


Source: SGS

Calorific Value

In the graph below it can be observed that the calorific value and ethanol have a linear relationship. Each 5% v/v of ethanol added decreases calorific value from 1.5-3% approximately.

Figure 232: Calorific Value of Gasoline + EtOH Samples

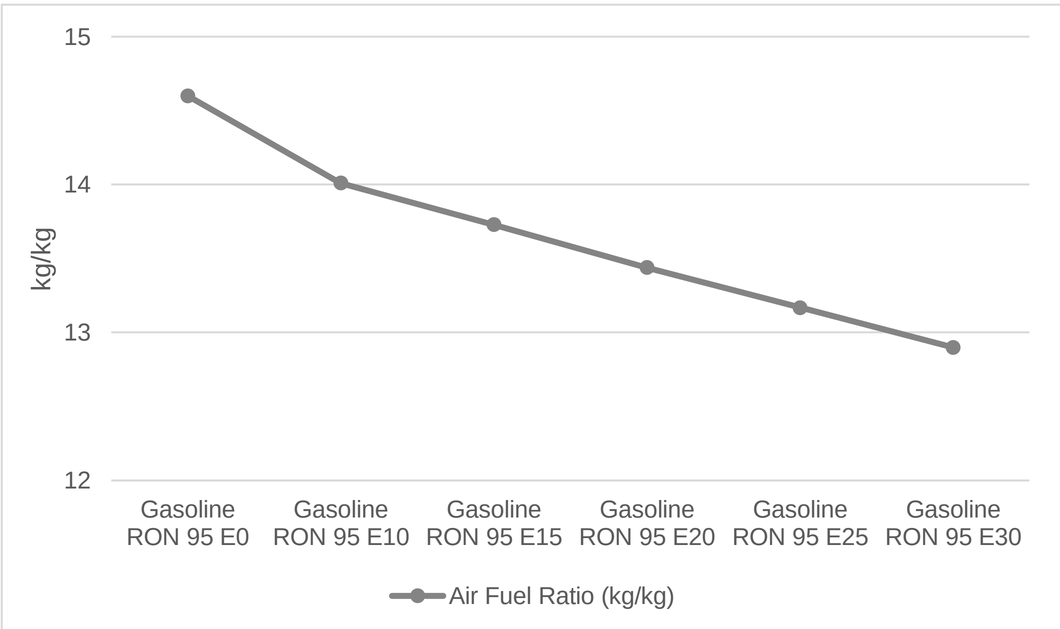


Source: SGS

Air-Fuel Ratio

In the graph below it can be observed that the air-fuel ratio and ethanol have a linear relationship, as for the calorific value. Each 5% v/v of ethanol added decreases air-fuel ratio 0.3 kg/kg approximately, except for the first addition of ethanol, where the drop is more significant.

Figure 233: Air-Fuel Ratio of Gasoline + EtOH Samples



Source: SGS

Other

The analysis of the samples shows no content of MTBE and anions and cations: silicon, iron, aluminum, copper, lead, tin, chromium, nickel, zinc, phosphorous, magnesium, calcium, sodium, molybdenum, barium, potassium, titanium, vanadium, boron, manganese, silver, cobalt and lithium.

Figure below summarizes values for all parameters studied for the gasoline grade and the ethanol blend grades.

Figure 234: Values for parameters for gasoline and ethanol grades in Guatemala

	Gasoline RON 95 E0	Gasoline RON 95 E10	Gasoline RON 95 E15	Gasoline RON 95 E20	Gasoline RON 95 E25	Gasoline RON 95 E30
RON		99.3	99	99.6	100	100
MON		85.6	86.3	87.2	87.4	87.2
Water Content (% m/m)	0.007	0.018	0.02	0.026	0.024	0.026
RVP (kPa)	63.9	70.8	69.7	69.5	68.5	67.8
Sulfur (mg/kg)	39.1	32.5	30	26.8	24.4	22.9
Oxygen content (% m/m)	0	3.71	5.39	7.23	8.9	10.55
Ethanol (% v/v)	0	9.91	14.33	19.28	23.81	28.32
Total oxygenates (% v/v)	0	10.02	14.7	19.8	24.44	28.92
Total paraffins (% v/v)	52	46.7	44.1	41.7	39.3	36.9
Total naphthenes (% v/v)	5	4.5	4.3	4	3,8	3.6
Total olefins (% v/v)	14.7	13.4	12.7	12	11.2	10.5
Total aromatics (% v/v)	28.4	25.4	24.2	22.5	21.2	20.1
MTBE (% v/v)	0	0	0	0	0	0
Benzene (% v/v)	1.55	1.42	1.35	1.26	1.18	1
Cations and anions (mg/kg)	0	0	0	0	0	1.11
Distillation T10 (ºC)	51.8	49.5	50.5	51.5	52.5	52.9
Distillation T50 (ºC)	99.6	83.3	71	71.8	72.5	72.9

Distillation T90 (ºC)	158	155	153.3	151	148.5	146.2
Distillation FBP (ºC)	205	204.8	200.7	199.7	199.5	196.9
Distillation residue (% v/v)	1.1	1.2	1.1	1.2	1	1
Calorific value of gasoline (MJ/kg)	43.37	42.08	41.48	40.85	40.27	39.69
Air Fuel Ratio (kg/kg)	14.6	14.01	13.73	13.44	13.17	12.9

Source: SGS

Peru

Key Takeaways

The samples for the analysis of parameters are based on gasoline with RON 90 and 7.8% v/v ethanol content. RON 90 is one of the regular grades and had 60% of the market share in 2020.

The RON 90 ethanol blend grade has a significantly higher octane than required. Even so, BOB in Peru is lower than in other Latin American countries. If ethanol would be added in higher concentrations, octane of the ethanol blends would increase, and this would benefit emissions. Furthermore, the oxygen limit of E10 is out of the scope of EU specifications, but this is because ethanol is splash blended with gasoline containing ethanol. Optimizing the BOB could reduce the oxygen content of the finished fuel. Sulfur and hydrocarbons are reduced with the addition of ethanol as expected. In the case of sulfur, aromatics and olefins, Peru would be closer to meet EU specifications if ethanol content in gasoline would be higher.

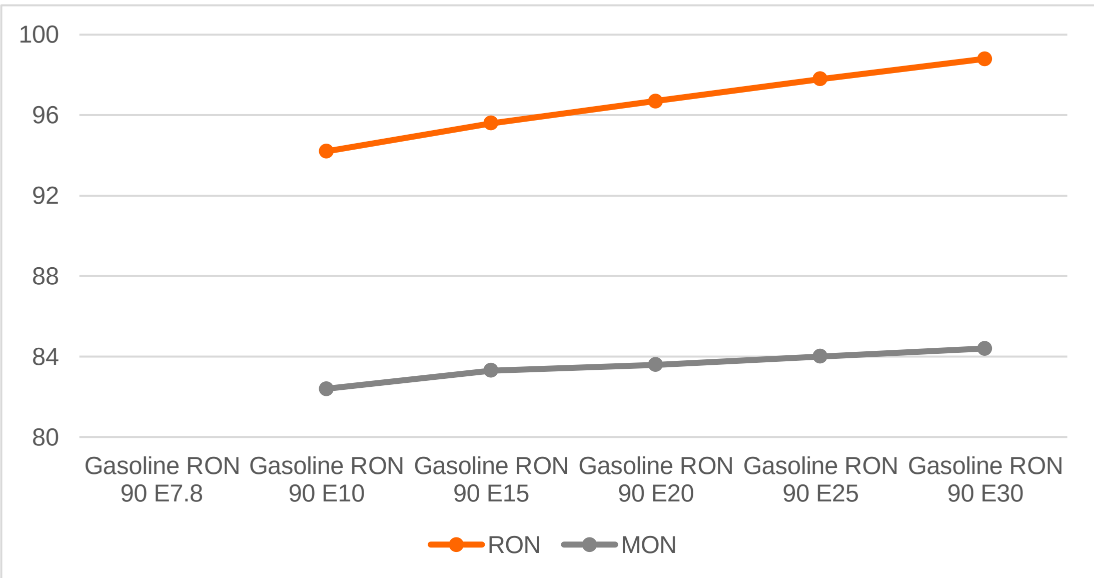
RVP increases significantly to achieve E10 from E7.8, but this is for the same reason as explained above. If ethanol would have been added to BOB, RVP would not increase so drastically. Water content decreases with the addition of ethanol but this is due to the quality of Peruvian and ethanol gasoline compared to EU ethanol, which is poorer in this case.

The addition of ethanol in gasoline does not affect distillation values of gasoline. The calorific value and the air-fuel ratio decrease but as expected, and do not affect the stability of the ethanol blend.

Octane

As can be seen below, Research Octane Number (RON) increases proportionally with the addition of ethanol. Motor Octane Number (MON) as well, but the increase is less pronounced. The *before oxygenate blending blendstock* (BOB) has a low RON, but E30 reaches a RON number similar to European premium gasoline.

Figure 235: RON and MON Values Gasoline + EtOH Samples

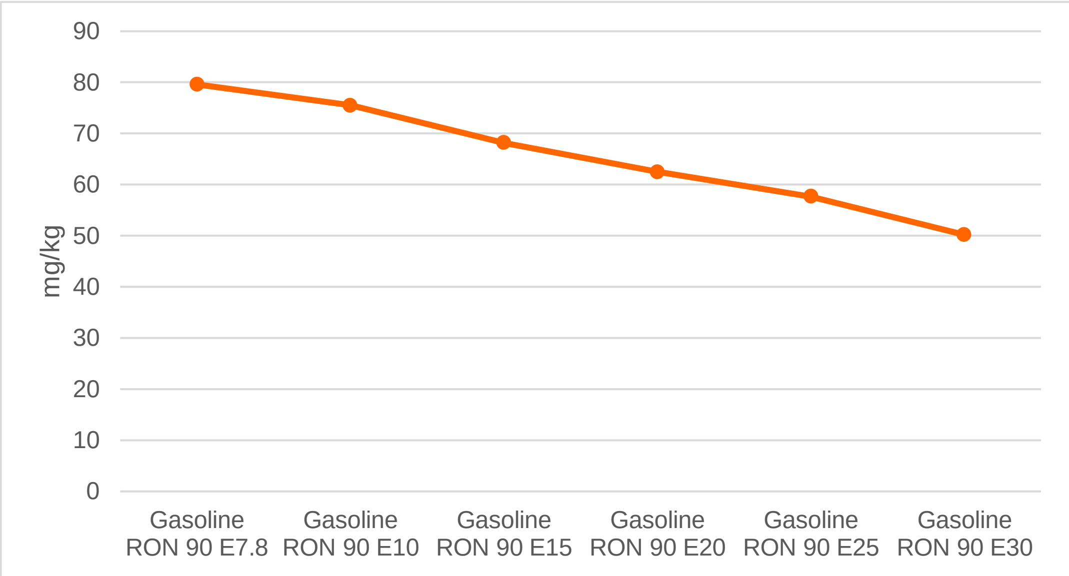


Source: SGS

Sulfur

Since ethanol does not contain any sulfur, the blending of ethanol in gasoline decreases the content of sulfur in the fuels. From E7.8 to E30, sulfur is reduced by 30 mg/kg.

Figure 236: Sulfur (mg/kg) in Gasoline + EtOH Samples

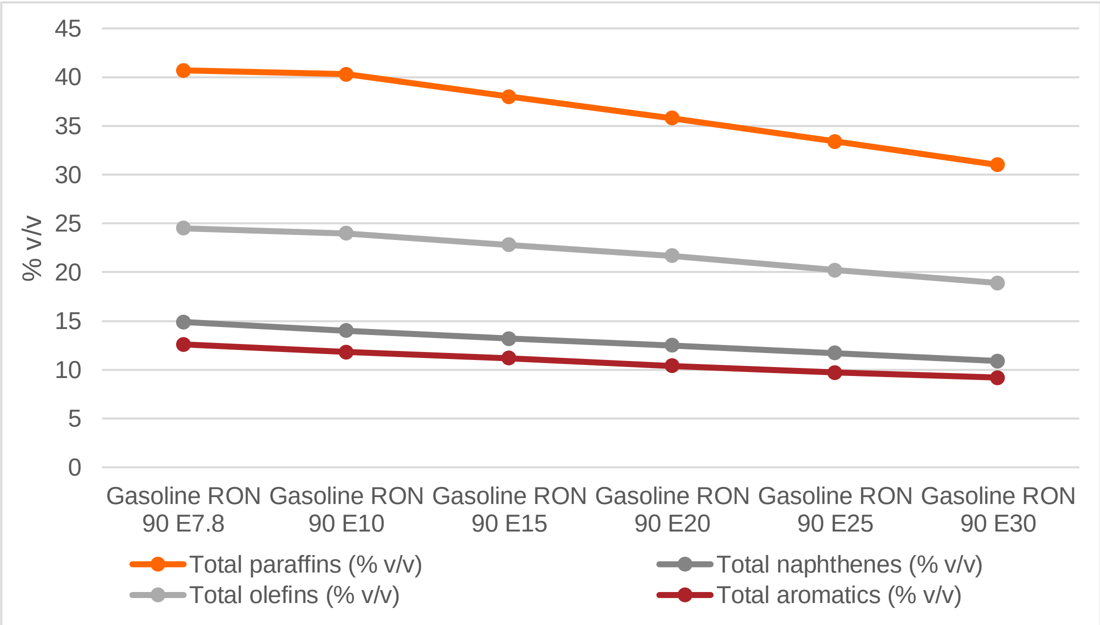


Source: SGS

Hydrocarbons

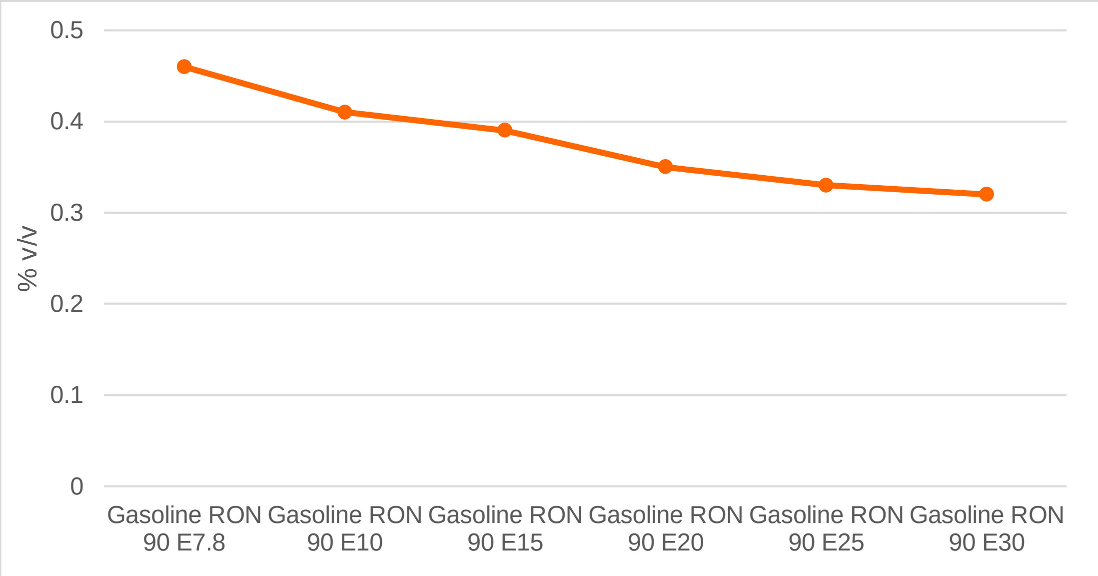
Since ethanol fuel does not contain hydrocarbons, the blending of ethanol in gasoline decreases the content of hydrocarbons in the fuel, particularly paraffins and aromatics.

Figure 237: Aromatics, Olefins, Paraffins and Naphthenes (% v/v) in Gasoline + EtOH Samples



Source: SGS

Figure 238: Benzene (% v/v) in Gasoline + EtOH Samples



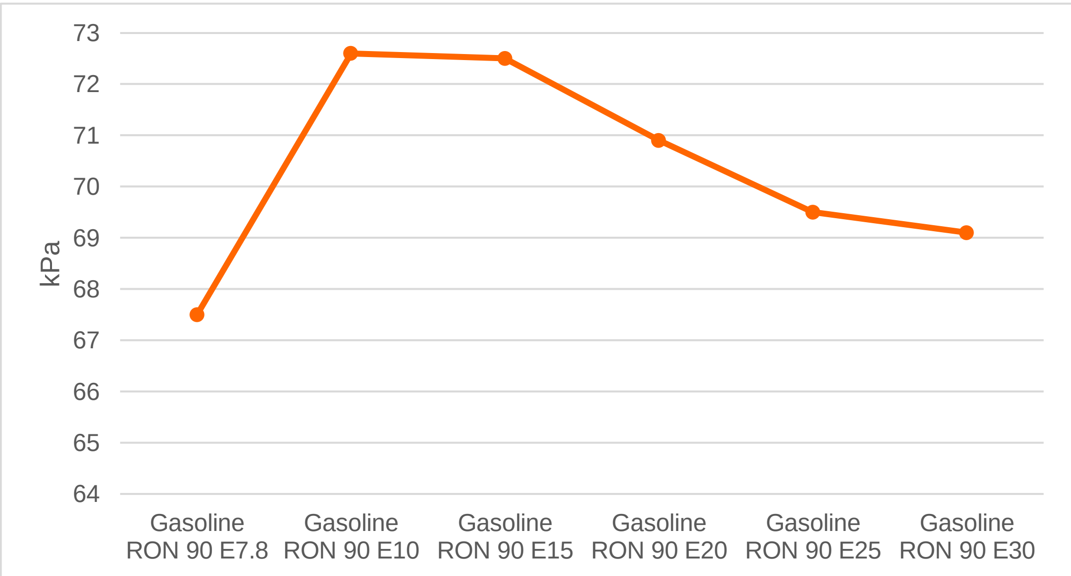
Source: SGS

Vapor Pressure (RVP)

According to the laboratory results, vapor pressure of gasoline starts increasing with the addition of ethanol in small quantities, it remains high until the ethanol reaches 15% v/v, when RVP starts decreasing. From E7.8 to E10, RVP increases 5 kPa. This is due to the addition of ethanol to an ethanol blend. If samples would have been formed by base gasoline without ethanol and ethanol would have been splashed blended in the laboratory, RVP increase at the beginning would have not been so pronounced.

After the addition of 25% v/v ethanol, the RVP decrease is less pronounced.

Figure 239: RVP Values Gasoline + EtOH Samples (37.8ºC)

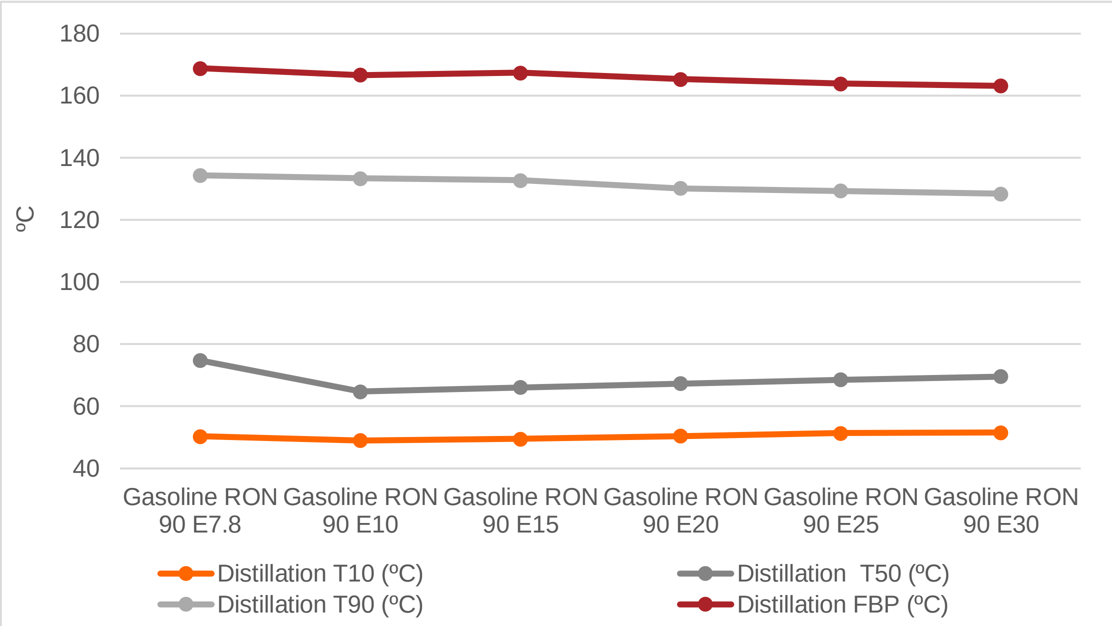


Source: SGS

Distillation

The addition of ethanol led to small changes in the distillation curves. It can be concluded that ethanol does not have a significant impact on distillation.

Figure 240: Distillation Evaporation Values (% v/v) in Gasoline + EtOH Samples

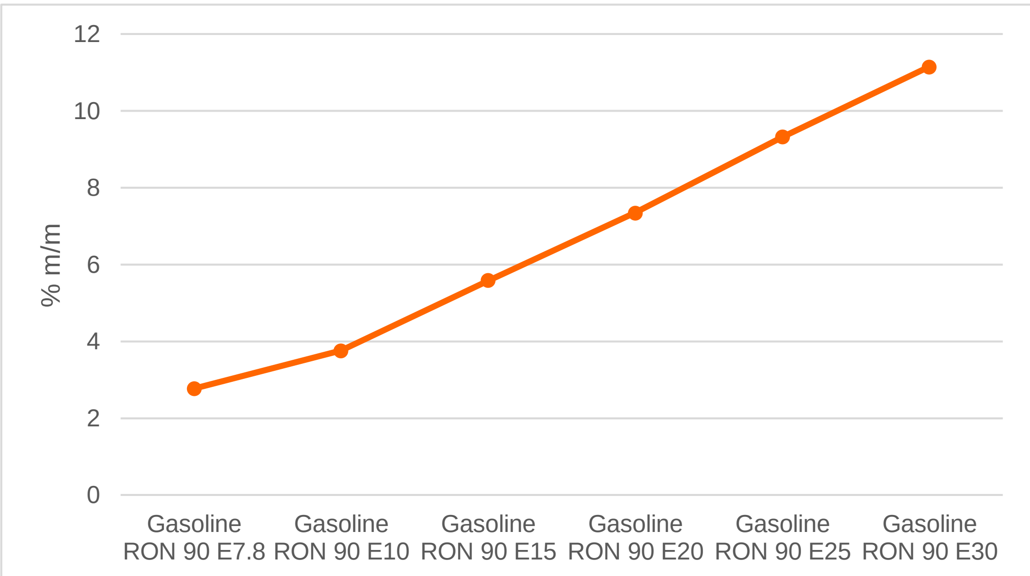


Source: SGS

Ethanol and oxygen content

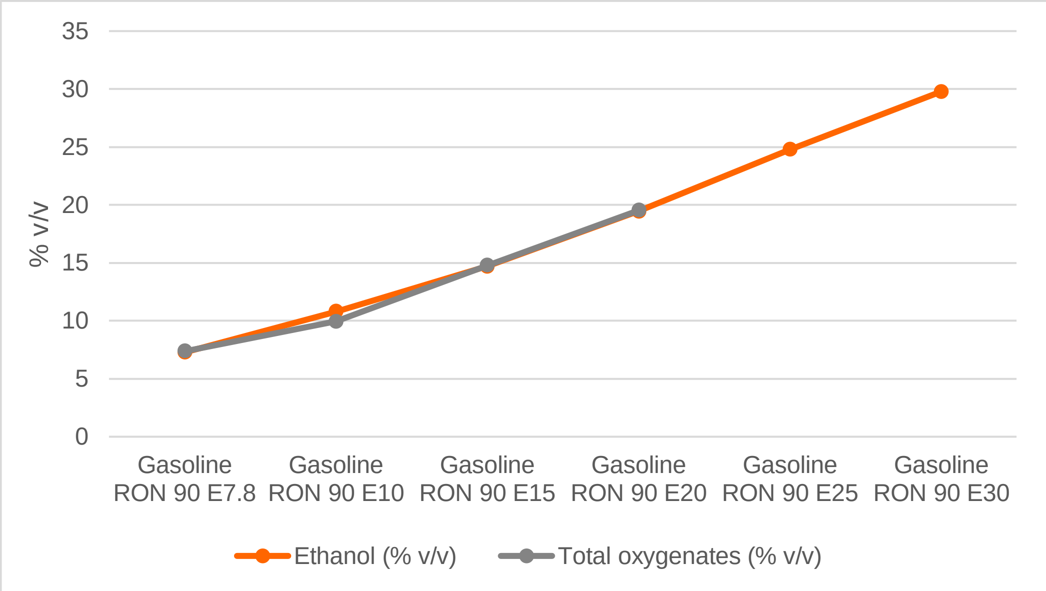
As observed below, the oxygen content increases proportionally with the addition of ethanol.

Figure 241: Oxygen content (% m/m) in Gasoline + EtOH Samples



Source: SGS

Figure 242: Ethanol and total oxygenate content (% v/v) in Gasoline + EtOH Samples

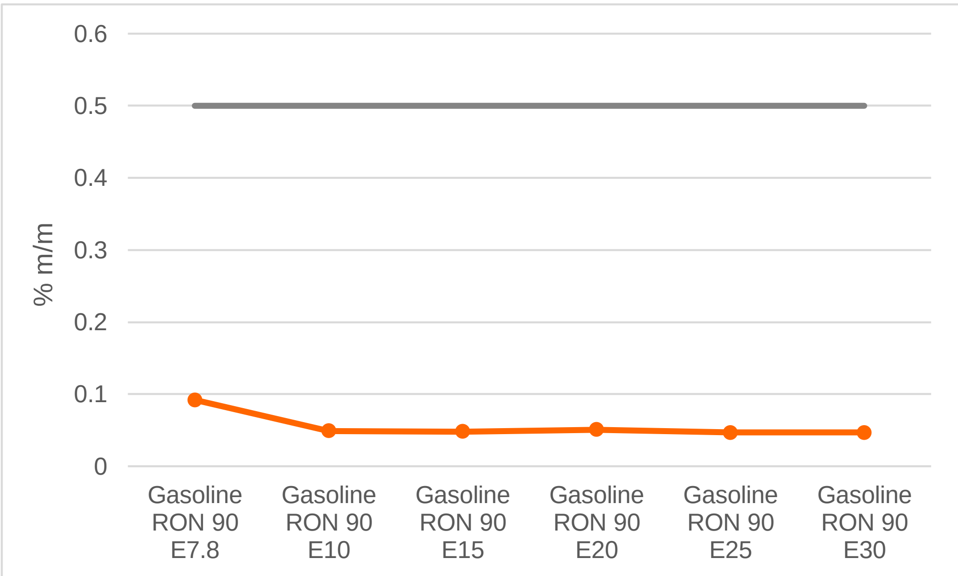


Source: SGS

Water content

The results show that the addition of ethanol does not impact on the water content of gasoline in the case of Peru after reaching E10. This is because water content in gasoline in Peru is three times higher than the ethanol used in the laboratory for the tests, which meets European specifications. In any case, water content is below the 0.5% v/v water content that can be dissolved in a 10% v/v ethanol blend with a typical hydrocarbon mixture at room temperature according to the ASTM D 4814 standard.

Figure 243: Water Content of Gasoline + EtOH Samples

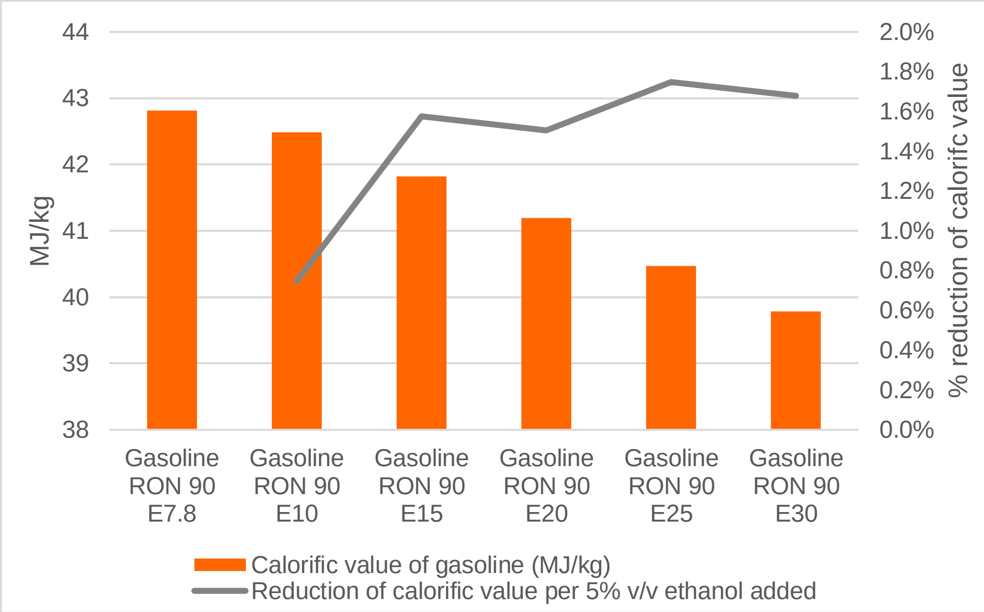


Source: SGS

Calorific Value

In the graph below it can be observed that the calorific value and ethanol have a linear relationship. Each 5% v/v of ethanol added decreases calorific value by 0.7-1.7% approximately.

Figure 244: Calorific Value of Gasoline + EtOH Samples

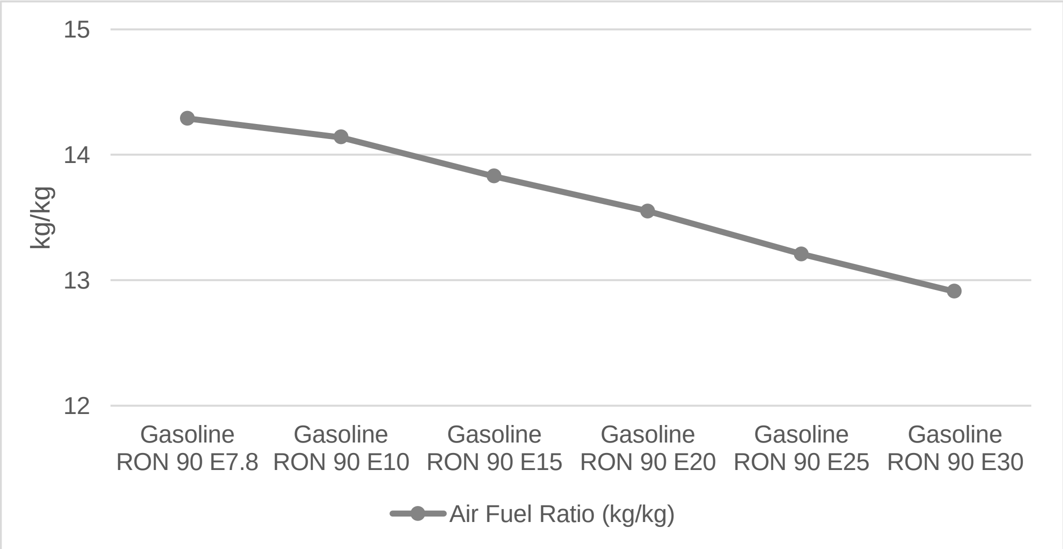


Source: SGS

Air-Fuel Ratio

In the graph below it can be observed that the air-fuel ratio and ethanol have a linear relationship, as for the calorific value. Each 5% v/v of ethanol added decreases air-fuel ratio 0.3 kg/kg approximately.

Figure 245: Air-Fuel Ratio of Gasoline + EtOH Samples



Source: SGS

Other

The analysis of the samples shows no content of MTBE and anions and cations: silicon, iron, aluminum, copper, lead, tin, chromium, nickel, zinc, phosphorous, magnesium, calcium, sodium, molybdenum, barium, potassium, titanium, vanadium, boron, manganese, silver, cobalt and lithium.

Figure below summarizes values for all parameters studied for the gasoline grade and the ethanol blend grades.

Figure 246: Values for parameters for gasoline and ethanol grades in Peru

PERU	Gasoline RON 90 E7.8	Gasoline RON 90 E10	Gasoline RON 90 E15	Gasoline RON 90 E20	Gasoline RON 90 E25	Gasoline RON 90 E30
RON		94.2	95.6	96.7	97.8	98.8
MON		82.4	83.3	83.6	84	84.4
Water Content (% m/m)	0.092	0.049	0.048	0.051	0.047	0.047
RVP (kPa)	67.5	72.6	72.5	70.9	69.5	69.1
Sulfur (mg/kg)	79.6	75.5	68.2	62.5	57.7	50.2
Oxygen content (% m/m)	2.77	3.76	5.58	7.34	9.32	11.15
Ethanol (% v/v)	7.28	10.8	14.71	19.46	24.77	29.77
Total oxygenates (% v/v)	7.37	9.94	14.78	19.52		
Total paraffins (% v/v)	40.7	40.3	38	35.8	33.4	31
Total naphthenes (% v/v)	14.9	14	13.2	12.5	11.7	10.9
Total olefins (% v/v)	24.5	24	22.8	21.7	20.2	18.9
Total aromatics (% v/v)	12.6	11.8	11.2	10.4	9.7	9.2
MTBE (% v/v)	0	0	0	0	0	0
Benzene (% v/v)	0.46	0.41	0.39	0.35	0.33	0.32
Cations and anions (mg/kg)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Distillation T10 (ºC)	50.4	49	49.5	50.5	51.4	51.6
Distillation T50 (ºC)	74.8	64.8	66.1	67.4	68.6	69.6
Distillation T90 (ºC)	134.4	133.4	132.8	130.2	129.4	128.5

Distillation FBP (ºC)	168.9	166.7	167.4	165.4	163.9	163.2
Distillation residue (% v/v)	1	1	1	1	1	1
Calorific value of gasoline (MJ/kg)	42.81	42.49	41.82	41.19	40.47	39.79
Air Fuel Ratio (kg/kg)	14.29	14.14	13.83	13.55	13.21	12.91

Source: SGS

GLOSSARY

Air-Fuel Ratio

Air–fuel ratio (AFR) is the mass ratio of air to a solid, liquid, or gaseous fuel present in a combustion process. The AFR determines whether a mixture is combustible at all, how much energy is being released, and how much unwanted pollutants are produced in the reaction. If exactly enough air is provided to completely burn all the fuel, the ratio is known as the stoichiometric mixture. Ratios lower than stoichiometric are considered "rich". Rich mixtures are less efficient but may produce more power and burn cooler. Ratios higher than stoichiometric are considered "lean". Lean mixtures are more efficient but may cause higher temperatures, which can lead to the formation of NO_X. Some engines are designed to allow lean-burn.

The AFR is the most critical item to regulate regarding exhaust emissions and fuel economy. The technically correct AFR may be calculated by knowing the molecular formula and weight of the fuel and writing an equation which presumes that all the carbon is oxidized to carbon dioxide (CO_2) and all the hydrogen to water (H_20).

Alkylates

Alkylates are a mix of high octane, low vapor pressure branched chain paraffinic hydrocarbons that can be made from crude oil through well-established refinery processes and are highly favored as streams for blending into gasoline.

Butanes

Butane is one of the lightest liquid streams typically produced in a refinery. The butane molecule has four carbon atoms and 10 hydrogen atoms. When blending into gasoline, butane is favored for its high octane but limited by its high vapor pressure. Butane is also frequently converted into isobutane for use as an alkylation feedstock.

Calorific Value

Calorific value can be defined as the amount of heat produced on combusting a unit volume of fuel and can be expressed in kcal/m^3, kJ/m^3, or BTU/ft^3.

Catalytic gasoline

Gasoline obtained from the Fluid Catalytic Cracking units.

Catalytic reforming

Catalytic reforming is a chemical process used to convert petroleum refinery naphthas distilled from crude oil (typically having low octane ratings) into high-octane liquid products called reformates, which are premium blending stocks for high-octane gasoline.

Denatured fuel ethanol

Ethanol made unfit for human consumption.

Distillation

Distillation is defined by the temperature at which a certain volume percentage of a liquid evaporates and is recovered by cooling.

The distillation characteristics of hydrocarbons have an important effect on safety and performance, especially in the case of fuels and solvents. The boiling range gives information on the composition, the properties, and the behavior of fuels during storage and use. Volatility is the major determinant of the tendency of a hydrocarbon mixture to produce potentially explosive vapors. The distillation characteristics are critically important for both aviation and automotive gasolines, affecting starting, warm-up, and tendency to vaporlock at high operating temperatures or at high altitude, or both. The presence of high boiling components in these and other fuels can significantly affect the degree of formation of solid combustion deposits.

Fluid catalytic cracking (FCC) and hydrocracking units

Refinery units used to break heavier products into products that can be blended to obtain gasolines.

Fluid catalytic cracking (FCC) naphtha

This is a naphtha range material with octane and vapor pressure close to the quality specifications for finished gasoline. This is typically the largest product at around 50% of FCC output.

Hydrocarbons

Gasoline mostly contains hydrocarbon components such as aromatics, olefins and benzene which are naturally present in crude petroleum.

The aromatics content in gasoline is directly linked to the pollution from the exhaust system of a gasoline engine. Therefore, reducing the aromatics content may reduce the total of hydrocarbon emissions from the engine. It may also reduce emissions from benzene and toluene, but it may increase aldehyde emissions. Exhaust 1,3-butadiene emissions are significantly higher at higher olefin levels, according to the U.S. Environmental Protection Agency (EPA). Moreover, benzene is a human carcinogen.

Hydrodesulfurization

Hydrodesulfurization (HDS) is a catalytic chemical process widely used to remove sulfur from natural gas and from refined petroleum products, such as gasoline or petrol, jet fuel, kerosene, diesel fuel, and fuel oils.

Hydrotreating

Hydrotreating is the reaction of organic compounds in the presence of high pressure hydrogen to remove oxygen (deoxygenation) along with other heteroatoms (nitrogen, sulfur, and chlorine).

Isomerates

Isomerate is a gasoline blend stock produced by the isomerization unit through increasing the octane of light naphtha.

Light straight run

Light straight run naphtha is a distillation cut made up of pentane and slightly heavier naphtha range material. It can come either from crude distillation or from fractionation of NGLs (natural gasoline).

The light naphtha distillation cut has three typical uses:

- Blending directly into a finished light naphtha product
- Feed to the isomerization unit to make isomerate for blending into gasoline
- Direct blending into gasoline

As a blend stock for making gasoline, light naphtha is of fairly low quality. It tends to have low octane and high vapor pressure. Hence, it typically only makes up a very small portion of the gasoline pool.

MTBE (Methyl-tert butyl ether)

MTBE is an oxygenate used as gasoline additive to increase octane.

Naphthas

Naphtha is a broad term referring to distillation fractions and other intermediates in the gasoline boiling range. Typically, naphtha is categorized based on its boiling range as either: light naphtha or heavy naphtha. Light naphtha is composed of pentane and slightly heavier material. Heavy naphtha molecules typically have from 7-9 carbon atoms. Its boiling range can be from 180ºF to 330ºF.

Natural gas liquids

Natural gas liquids (lease condensate, natural gasoline, NGL) are components of natural gas that are liquid at surface in gas or oil field facilities or in gas processing plants. The composition of the natural gas liquids is dependent upon the type of natural gas and the composition of the natural gas.

Natural gas liquids can be classified according to their vapor pressures as low (condensate), intermediate (natural gasoline), and high (liquefied petroleum gas) vapor pressure. Natural gas liquids include propane, butane, pentane, hexane, and heptane, but not methane and not always ethane since these hydrocarbons need refrigeration to be liquefied.

Octane

The octane number represents the resistance of a spark ignition engine to knock (unwanted detonation which can damage the engine). The high intrinsic octane number of ethanol is well known. However, a greater effectiveness of octane number can be achieved through the knock resistance provided by the high level of vaporization cooling that occurs when ethanol is directly injected into the engine cylinders. Therefore, the higher the octane is, the lesser emissions are expected due to a good engine performance.

Oxygen content and oxygenates

Oxygenated organic compounds, such as MTBE and ethanol, often are added to gasoline to increase octane or extend gasoline supplies. Oxygenating the fuel may affect vehicle emissions (tailpipe, evaporative or both), performance and/or durability[4], and that is why oxygen content in gasoline is controlled.

Pyrolysis gasoline

Pyrolysis gasoline is a highly aromatic naphtha range intermediate produced as a by-product of making ethylene in a steam cracker.

Pyrolysis gasoline can be used as a high-octane gasoline blendstock or as a source of aromatics for BTX extraction.

Raffinates

The term also has been more generally used in reference to any low octane product left over after any secondary refining process.

Reformates

Reformate is a gasoline blending stock that is produced by the catalytic reforming, a refining process in which mixed-catalysts and hydrogen promote the rearrangement of lower octane naphthenes into higher octane compounds without a significant reduction in carbon number.

SGS's Shipping On-line (SOL)

Internal SGS data system that monitors trade flows of commodities in natural resources sector (oil and gas, agricultural commodities, and minerals). It tracks vessels' voyages with details on volumes and types of cargoes and types of operations in ports.

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[4] https://www.acea.auto/files/WWFC_19_gasoline_diesel.pdf

Sulfur

Crude petroleum is mainly composed of hydrocarbon components and other components including organic and inorganic sulfur containing compounds. Sulfur is the third most found element in crude petroleum after carbon and hydrogen. High sulfur contained in crude petroleum is more complicated and more expensive to refine. Thus, sulfur is still found in refined petroleum products including gasoline.

Sulfur in fuel enhances metal corrosion in the engine, the fuel system, and the after-treatment system. In addition, it increases the sulfur-oxides emissions from the vehicles. For those reasons, sulfur content in fuels, including gasoline, should be limited.

Vapor Pressure (RVP)

A minimum vapor pressure is required to ensure good cold starting and drivability. A maximum vapor pressure is required to control the evaporative emissions from the vehicle. Therefore, requirements contain both a high and a low threshold.

Pure ethanol has a lower vapor pressure compared to gasoline and the alcohol-gasoline mixtures have a significant impact on the volatility properties. The RVP increases with the addition of methanol, and decreases with the addition of isopropanol, tertbutanol and isobutanol compared to base gasoline. When ethanol is added to gasoline up to 10% v/v, the vapor pressure of the mixture increases compared to the vapor pressure of base gasoline. Above E10 blend it decreases.[5]

In conclusion, vapor pressure is a smaller problem for high blends of ethanol (above 10% v/v); for low blends it could be handled by adjusting the before oxygenate blending (BOB) at the refinery.

[5] The Volatility of Reformulated Gasolines with Alcohols

LIST OF SOURCES

- Secretary of Energy of Argentina
- Argentinean Association for Biofuels and Hydrogen
- U.S. Energy Information Administration (EIA)
- Transport Energy Strategies
- European specifications (CEN)
- European Commission
- HCX
- Wood Mackenzie PennEnergy Research
- Worldwide Fuel Charter
- Oil and Gas Journal Data
- Ministry of Energy and Mining of Argentina
- The National Administration of Fuels, Alcohol, and Portland of Uruguay (ANCAP)
- Ministry of Industry, Energy and Mining of Uruguay
- The Regulatory Body for Energy and Water Services (URSEA)
- The Uruguayan Institute of Technical Norms (UNIT)
- Alcohols of Uruguay (ALUR)
- National Energy Commission of Chile
- Ministry of Energy of Chile
- Department of Electricity and Fuels of Chile (SEC)
- National Oil Company from Chile (ENAP)
- Ministry of Mines and Energy in Colombia
- National Council of Economic and Social Policy of Colombia
- Fedebiocombustibles
- Unit of Mining and Energy Planning of Colombia
- ECOPETROL, Refinery of Cartagena, Colombia, 2019
- National Hydrocarbons Agency of Colombia, ANH
- Colombian Oil Association, ACP
- Ministry of Hydrocarbons and Energy of Bolivia
- Bolivian oil company, YPFB
- The National Agency for Hydrocarbons in Bolivia, ANH
- Ecuadorian Norms Service (NTE INEN)
- Ministry of Industry of Ecuador
- Petroecuador
- Biofuels Association of Ecuador, APALE
- Energy Regulatory Commission, Mexico
- Secretary of Energy of Mexico
- PEMEX
- Ministry of Energy and Mines of Peru
- The National Institute for the Defense of Competition and Protection of Intellectual Property of Peru
- Supervisory Agency for Investment in Energy and Mining of Peru (OSINERGMIN)
- U.S. Department of Agriculture
- Secretariat of Central American Economic Integration (SIECA)
- Ministries Council for Economic Integration of Central America (COMIECO)
- The Institute of Technical Standards of Costa Rica

- Ministry of Commerce and Industries of Panama
- Ministry of Energy and Mines, General Directorate of Hydrocarbons of Nicaragua
- RECOPE
- Ministry of Economy, Directorate of Hydrocarbons and Mines of El Salvador
- Ministry of Energy and Mines of Guatemala
- Economic Commission for Latin America and the Caribbean (CEPAL)
- Energy Secretary of Honduras
- National Energy Secretariat of Panama
- National Institute of Statistics and Census of Panama
- United Nations Comtrade
- Bureau of Standards of Jamaica
- Ministry of Energy of Jamaica
- Dominican Institute for Quality (INDOCAL)
- Magazine “Ciencia, Economía y Negocios”, Dominican Republic
- Science Direct
- McKinsey Energy Insights
- IHS Markit
- World Health Organization
- U.S. Environmental Protection Agency
- International Agency for Research on Cancer
- National Renewable Energy Laboratory from the United States
- The University of Illinois at Chicago
- California Environmental Protection Agency

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Current status: September 2021

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